IDENTIFICATION OF USES OF INCREASED STREAMFLOW ASSOCIATED WITH VEGETATIVE MODIFICATION IN THE VERDE RIVER BASIN

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Report Submitted to

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by

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EXECUTIVE SUMMARY

This study discusses probable recipients and uses of additional streamflow resulting from vegetation modification on national forest land. A procedure is presented that combines the use of a stochastic hydrologic model with a legal and institutional analysis. Three scenarios are studied to analyze the allocation of additional flows, including: (1) assuming current legal and institutional arrangements; (2) assuming implementation of Plan 6, the regulatory storage component of the Central Arizona Project; and (3) assuming adoption of a Modified Plan 6.

In Chapter I, past vegetation modification activities in Arizona are highlighted. The objectives, methods and assumptions made in the study are also presented.

Chapter II describes the physical and socioeconomic setting of the Salt-Verde River watersheds and the downstream Phoenix metropolitan area. It also examines laws and policies that form the legal and institutional framework for water management in the study area.

Chapter III provides an overview of the major parties at interest that would be affected by a program of vegetative modification on the Coconino, Kaibab and Prescott National Forests. They include the USDA Forest Service, water users in the Upper Verde River and Upper Salt River Valleys, the Salt River Project, the cities that make up the greater Phoenix metropolitan area, several irrigation districts, several Indian Reservations and a number of Arizona State agencies. The legal claims of these interests to capture water are described, and current use patterns are noted.

To route the additional flow through the reservoir system, a reservoir management and water allocation computer model was adopted and coupled to

first-order Markov models for simulating flows in the Salt and Verde Rivers. This procedure is described in Chapter IV. The combined model was used to determine which account received the credits of the additional flow under current legal and institutional arrangements. Variations of the combined model were used to determine the accounts to which the additional flow would be credited under Plan 6 of the CAP, and under Modified Plan 6, a scenario using 50 percent of Cliff Dam's flood storage as conservation storage. The models were each run for three levels of increase: 100, 50 and 10 percent of possible additional flow. Each scenario was run for 100 ten-year periods, with the results being represented in the form of probability distributions.

Chapters V and VI focus on the possible users and uses of water made available under vegetative modifications programs. The Chapter V examines the potential beneficiaries under current legal-institutional arrangements, while Chapter VI examines changes that would occur if Cliff Dam were built on the Verde River to provide new conservation storage.

Under the existing system, most of the additional water produced by vegetation modification would be spilled at Granite Reef Dam. Some of the spilled water could recharge aquifers in the Valley. The remaining increase in supply would go to the Salt River Project and to the City of Phoenix. In each case the additional water would most likely be used to offset groundwater pumping.

If Plan 6 or a Modified Plan 6 were constructed, spills at Granite Reef Dam would be reduced. The largest share of the remaining additional flow would be allocated to the SRP and to Plan 6, although the actual user or users of Plan 6 water cannot be determined at this time.

I. INTRODUCTION

A. Statement of the Problem

Vegetative modification to increase watershed runoff has been carried out on an experimental basis for nearly twenty years in Arizona. Most of the work that has been done in the state has occurred in the Salt and Verde River watersheds, an area that is a major source of the available surface water supply in Arizona. The potential for vegetative modification is significant on these watersheds due to the size of the watersheds, vegetation types, and available precipitation. There are also existing storage facilities which could possibly capture and store increased yields for downstream use.

In 1956, a cooperative study involving the Arizona State Land Department, the University of Arizona, and the Salt River Valley Water Users' Association investigated the feasibility of increasing water yield from the Salt and Verde River basins. The study examined methods of manipulating forest and range lands to increase surface water production. Methods described that would reportedly result in the availability of up to 285,000 acre-feet per year of additional surface water included: drastic thinning of ponderosa pine stands, management of low productivity pines chiefly for water yield, thinning of spruce to favor snow deposition, expanded eradication of juniper and pinyon pine, and the modification of stream-side vegetation to reduce the loss of water between the point of production and the reservoirs. The resulting report, commonly known as the Barr Report (1956), concluded that increasing runoff from watersheds into rivers and reservoirs was one of the most promising methods for increasing the state's water supply.

As a result of the Barr Report, the Arizona Water Resources Committee (AWRC), a citizen's committee composed of interests in support of increasing water yields, was formed to promote research, action, and public relations projects related to watershed treatment programs. While the committee hoped to launch a major effort, implementation of a large-scale action program proved to be politically unacceptable. Because the underlying assumptions of the Barr Report had not been sufficiently tested and critics of the program questioned their validity, the committee decided to focus its subsequent work on development of an adequate research base.

In the mid-1960s, the AWRC again attempted to launch an action program, supporting a cooperative program involving the Salt River Project and the USDA Forest Service. This program anticipated expenditures of $75 million to increase average yields from the Salt-Verde watershed from 795,000 acre feet to over one million acre feet (Salt River Project, 1964). However, public opposition to the use of herbicides to defoliate and kill chaparral resulted in cancellation of the program in 1971. Research again became the principal thrust of the committee.

A third attempt to foster an action program began in 1975, with release of the Ffolliott-Thorud Report, <u>Water Yield Improvement by Vegetation Management: Focus on Arizona</u>, and two summary publications. Based on the reports' finding, the AWRC concluded that enough scientific information had finally been gathered to begin a full-scale operational program. However, expressed public concerns about who would benefit, and the impact of watershed treatments on other forest values, again blocked implementation of such a program.

In 1979, the Forest Service's Rocky Mountain Forest and Range Experiment Station produced several reports--each focused on a different vegetative type--summarizing the research that had been done up until that

time (Hibbert, 1979, summarizes these reports). In 1981, additional estimates of water yield increases were made by the Forest Service (Solomon and Schmidt, 1981). While these projections were lower than previous estimates made by the Forest Service and the Ffolliott-Thorud Report, they also showed that significant opportunities did exist for increasing water yield on Arizona's national forest lands (Solomon and Schmidt, 1981).

While the techniques of increasing water yields through vegetative manipulation have been well documented (Hibbert, 1979; Troendle 1983), there is still uncertainty about the effects of such increases on downstream uses. Given the stochastic nature of water regimes, questions remain about whether projected increases can be physically demonstrated in downstream reservoirs or points of use, even if transmission losses are negligible (Hibbert, 1979). Other hydrological problems involve the relationship between historical flow data and predicted increases from treated areas, the amount of reuse of additional streamflow that will occur, and the hydrological interactions between surface water runoff and recharge of the groundwater supply.

Equally as important as unraveling the hydrologic interactions that will affect the amounts of water available for downstream flows is the problem of untangling the complex web of water rights, laws, and institutions that govern water allocation and use in the study area. Questions about what uses and users would benefit from additional flows have long been prominent issues surrounding proposals to use vegetative manipulation techniques on Arizona's watersheds (Cortner and Berry, 1978). Critics, for example, have long charged that additional water supplies would not be available for game or fish or recreation, and that only the Salt River Project (the major downstream irrigator) would be able to use

the additional water. Past economic analyses (Brown et al., 1974) have assumed that the additional flows would be consumed by the agricultural sector for use in growing low-valued feed grain or forage crops (Hibbert 1979). However, rapidly expanding urban populations in the Phoenix area, water needs of the area's energy producers, and revisions in the laws and institutions governing the pricing, administration, and distribution of water are complicating the institutional picture. Past assumptions about the factors that would affect water distribution and use from increased streamflows may no longer be valid. Further changes in legal-institutional arrangements could result in additional flows being put to higher valued users than under existing arrangements.

It is clear that many of the unresolved issues regarding augmentation through vegetative manipulation now center on interactions occurring beyond the point of treatment on the watershed. Several of the most important issues involve economic, political, and legal questions. It is important that the current and potential users of any additional water from vegetative modification be identified. Once identified, work can proceed to better determine what economic values can be attached to the benefits of modification activities.

As a prelude to further cost-benefit analysis, the Rocky Mountain Forest and Range Experiment Station is conducting several studies to investigate the hydrologic interactions that will affect the amounts of water available downstream and what users and uses will benefit from the additional flows. This work is being down for three river systems: the Rio Grande, the Colorado, and the Salt-Verde. This report focuses on the Salt-Verde system.

B. Purpose of Study

The purpose of the report is to determine how additional quantities of water leaving ponderosa pine and chaparral areas of the Coconiño, Kaibab and Prescott National Forests in northern Arizona as a result of vegetation modification and entering the Verde River would affect existing or potential water users (Figure 1). The report combines hydrological data with legal-institutional and water distribution information. It is intended to be useful to the Forest Service in estimating the economic benefits of additional streamflow in the course of analyzing potential vegetative modification on the forests. There are four objectives of the report:

(1) Identify and compare the array of legal-institutional arrangements that currently affect water distribution and use in the Salt-Verde River system;

(2) Describe existing water users and water use patterns in locations that may be affected by additional flows;

(3) Predict how, under existing institutional arrangements, three alternative levels of additional water runoff entering the Verde River would affect downstream water use and users between 1985 and 1995, assuming that the corresponding vegetative modification were completed by 1985.

(4) Identify changes in legal-institutional arrangements, especially those associated with the building of Cliff Dam on the Verde River, that might result in a new mix of water use patterns during the study period.

Maps Source: Verde River, Wild and Scenic River Study

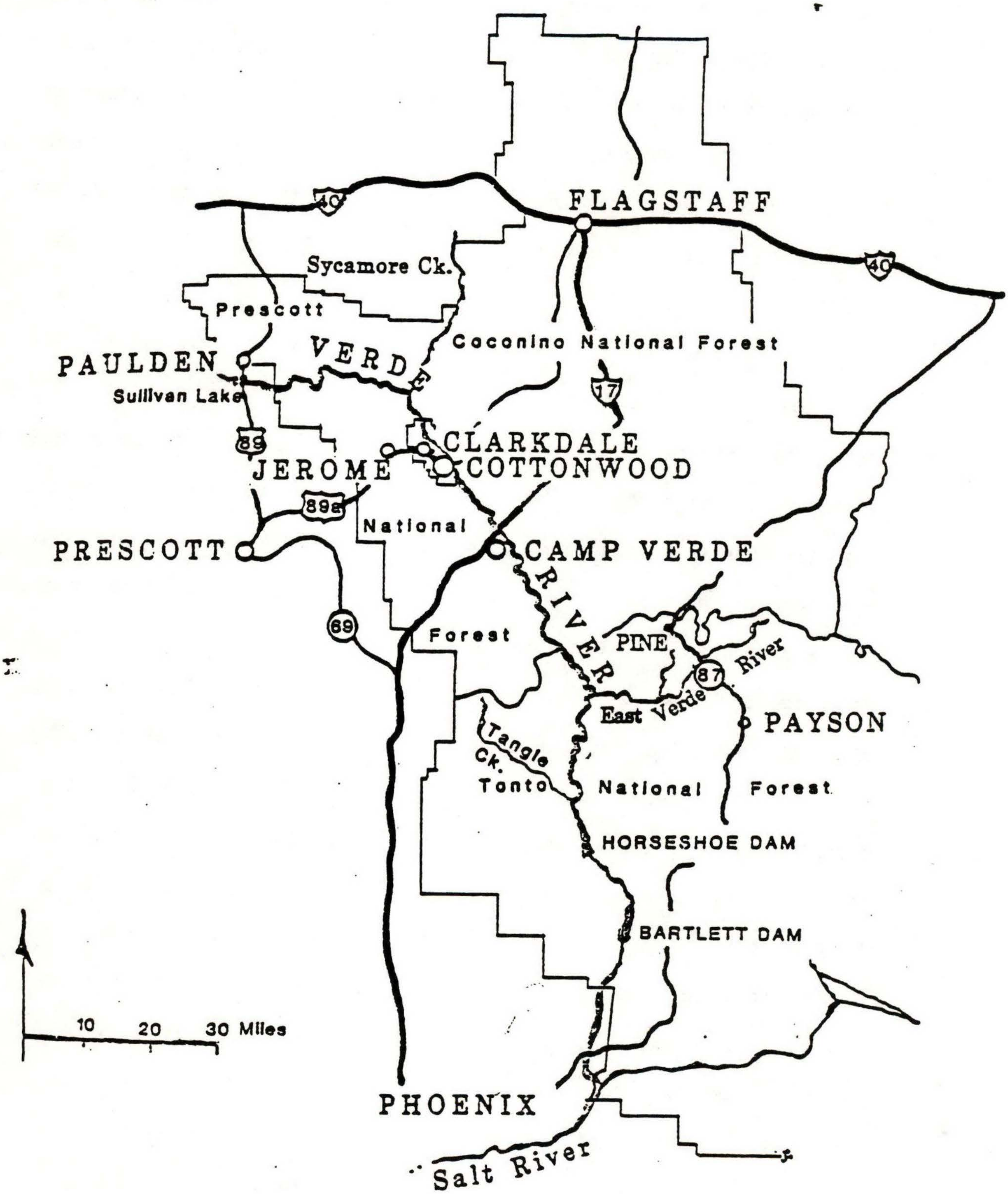


Figure 1 Location Map

C. Methods

Hydrologic

Synthetic stream flow records were generated for the Salt and Verde Rivers using first-order Markov models based on 93 years of historical monthly stream flow records. The stream flow increases due to vegetation modification on the national forests drained by the Verde River were characterized according to return period of pre-increase flow in the Verde River and then added to the respective pre-increase flow to estimate post-increase flow.

The pre-increase and post-increase flows were, via computer simulation, separately routed through the reservoir systems on the Salt and Verde Rivers and allocated to different use, spill, and loss categories. The time period of the study was ten years. One hundred ten-year periods were simulated for each scenario, with random numbers to account for the stochastic nature of the stream flow. The 100 simulations for each scenario were summarized in terms of the distribution of the possible outcomes from the ten-year period. In addition, distributions of what happened in the tenth year of each simulation were developed to show yearly extremes. In each case, the post-increase allocations minus the pre-increase allocations indicated the allocation of the increase.

The simulations were made for three scenarios. The first scenario was the current reservoir and operating rules on the Verde and Salt Rivers. The second was the Plan 6 of the Central Arizona Project in place including Cliff Dam and the addition to Roosevelt. The final scenario was the same as the second with the exception of using 50 percent of the flood control space in Cliff for conservation storage from April to November each year. Each scenario was simulated for three separate levels of runoff increase:

100 of what could potentially be expected from vegetative treatments in the watersheds, 50 percent and 10 percent.

The additional flow was only generated in the Verde watershed. Because the reservoirs on the two rivers are operated in conjunction, however, each of the three scenarios required simulating flows and reservoir management on both the Salt and the Verde Rivers.

Legal-Institutional

The first task involved examining current legal-institutional arrangements. This was accomplished by combining a literature search with interviews of key personnel.

Legal documents (statutes, judicial decision, and legal literature) were searched to identify the legal framework within which water rights on the Salt and Verde Rivers have been established. Government documents (congressional hearings, environmental impact statements, annual reports), were examined to identify the principal water users whose interests would be affected by increased streamflows.

Interviews with key personnel were used to verify existing water rights to Salt-Verde water, and explore claims that would attach to increased water flows under existing legal-institutional arrangements. Personnel from the following organizations were contacted: Salt River Project, City of Phoenix, Arizona Department of Water Resources, Arizona Municipal Water Users Association, Central Arizona Water Conservation District, Prescott Active Management Area, Arizona Agri-Business Council, Arizona Game and Fish Department, U.S. Bureau of Reclamation, and the Indian communities.

The second task involved identifying feasible changes in laws, institutions, and distribution networks that could occur within the next

10-20 years. This task was accomplished through a process of personal interviews done in conjunction with the first task. These changes were then analyzed to determine how they could affect uses of water and claims to additional streamflows.

D. Assumptions

Several important assumptions were made at the outset of the study. Three of the assumptions dealt with the development and implementation of a vegetative modification program on national forests. First, it was assumed that the full level of runoff increase from vegetative modification on the national forests would be available immediately, beginning in 1985. This is, of course, unrealistic because no decision to proceed with any of the three treatment scenarios used for analytical purposes in this report has been made and because, even if such a decision had been made, several years of treatments would be necessary to have treated sufficient acreage to reach the postulated increase. These assumptions were necessary to allow analysis of the effect of runoff increases on water uses and users under current institutional and legal arrangements. A more realistic runoff increase scenario, incorporating very gradual runoff increases as a result of treating a few acres each year beginning in 1985, would have resulted in significant levels of runoff increases only being reached sometime in the future, when the legal and institutional situation would probably be quite different from what it is now. Because legal and institutional changes are difficult to predict, it was decided to focus on the current institutional and legal setting. Concomitantly, it was assumed that a continuous supply of water would be available from the watersheds, i.e., once a vegetative manipulation program was implemented, it would be maintained. Third, it was assumed that the increase in water runoff expected from vegetative

modification activities would reach Horseshoe Reservoir and thus points of use downstream.

A fourth assumption dealt with future conditions. Because the future is never certain, only a finite number of future scenarios could be selected for analysis. Countless number of combinations of physical events, changes in values and attitudes, and political developments will affect the future water picture in Arizona. There is no way all contingencies can be foreseen. To be manageable, only those future contingencies that appeared the most realistic from today's vantage point were investigated. Accordingly, the decision to proceed with the building of Cliff Dam was viewed as the most likely change, and the one that potentially would have the most far-reaching institutional ramifications.

Finally, this report accepts the three levels of increase as "givens". Detailed analysis of the physical and biological feasibility of those levels was not made, and no analysis of the political feasibility of the vegetative treatments was made. Moreover, no calculations of the economic costs of a program of vegetative modification were entered into the analysis. Considerable controversy in the past has been generated in the state when groups have seized upon analytical maximums and treated them like achievable goals (Cortner and Berry 1978). Thus, the reader is cautioned that the postulated levels of runoff increase are used herein for analytical purposes only.

E. Outline of the Report

Following an introductory chapter which states the problem and presents the methods, Chapter II sets the stage. It describes the physical and socioeconomic setting of the Salt-Verde River watersheds and the laws

and policies that form the legal and institutional framework for water management.

The major parties of interest that would be affected by a program of vegetative modification on the national forests of the upper Verde Rivers are described in Chapter III. The legal claims of these interests to capture water are described, and current use patterns are noted.

Chapter IV describes the analytical model that was used to analyze stream flow data and the hydrologic model used to simulate river and reservoir conditions with and without water increases entering from the national forests.

Chapters V and VI focus on the possible uses and users of water made available under vegetative modification programs. Chapter V examines the potential beneficiaries under current legal-institutional arrangements (the first scenario), while Chapter VI examines changes that would occur if Cliff Dam were built on the Verde River to provide new conservation storage (the second and third scenarios). How the resolution of other uncertainties in law or policy would affect water users and uses is also noted. Finally, Chapter VII summarizes the principal findings and conclusions of the study.

II. THE PHYSICAL, SOCIOECONOMIC, AND INSTITUTIONAL SETTING

A. Physical Setting

The Salt and Verde Rivers, and their tributaries, are the principal stream systems found in the Central Highlands Province of Arizona. This geologic area is the source of approximately 50 percent of all streamflow originating in the state. The Salt and Verde Rivers provide about 93 percent of the developed surface water supply in the Salt River Valley (Arizona Water Commission, 1978). The largest landowner in both watersheds is the federal government. Through activities of the Forest Service, and as trustee for the Indian tribes, the federal government manages approximately 88 percent of the land in the watersheds (Barr 1956).

There are six reservoirs in the Salt-Verde system: Bartlett and Horseshoe on the Verde; and Stewart Mountain, Mormon Flat, Horse Mesa, and Roosevelt on the Salt. The reservoirs are designed to store water for use when needed on Salt River Project lands in the Phoenix area. The combined storage of these reservoirs is now 2,019,102 acre-feet. On the Verde River, the total storage capacity for Horseshoe,and Bartlett reservoirs is 309,613 acre feet with the remaining 1,709,489 acre feet on the Salt River (US Geological Survey, 1982; Arizona Water Commission, 1978; Salt River Project, 1985). Below Bartlett Dam, water is diverted for municipal use by the City of Phoenix, and irrigation on the Fort McDowell Indian Reservation. The remainder is diverted 27 miles downstream at Granite Reef Dam, below the confluence of the Salt and Verde Rivers, for agricultural, municipal and industrial uses.

Among the important factors influencing reservoir operation in the Salt-Verde system are hydroelectric facilities and relative storage-to-flow relationships. First, the 4 Salt River dams have hydroelectric facilities,

while the Verde dams have none. Thus, the reservoirs are usually operated so that consumptive water demands during periods of low power demand are satisfied from the Verde, thereby saving water in the Salt reservoirs for release during the hot summer months when power demand and the value of power is high. Second, the Verde has considerably less storage relative to inflow than does the Salt. Verde storage capacity is capable of holding about two-thirds of the historical annual inflow, while Salt storage capacity is 2.3 times average inflow. Thus, drawing down the Verde reservoirs significantly in the winter months helps contain heavy spring runoff events on the Verde.

The watershed area of the Salt River above Granite Reef Dam is 6,249 square miles and consists of the drainage areas of White River, Black River, and Salt River, including Carrizo Creek, Cibeque Creek, Canyon Creek, Cheery Creek, and Tonto Creek, plus some smaller basins (Figure 2). The Black River originates in the Apache National Forest. Upon leaving the forest, it forms the boundary between the San Carlos and the Fort Apache Indian Reservations. At the confluence of the Black and the White River (the White River is contained entirely within the Fort Apache Reservation), the Salt River begins. The Salt River then forms the boundary between the two reservations. At the western boundary of the San Carlos Indian Reservation the Salt River enters the Tonto National Forest. It flows through the forest until it reaches the Salt River Indian Reservation.

The Verde River watershed consists of 6,649 square miles above the confluence of the Salt and Verde Rivers near Granite Reef Dam. The Verde River originates in big Big Chino Valley north of Prescott, Arizona, and flows 125 miles east and then south through private and public lands before joining the Salt River. To the north and east, the watershed is defined by the Mogollon and Coconino Plateaus while to the south and west the Black

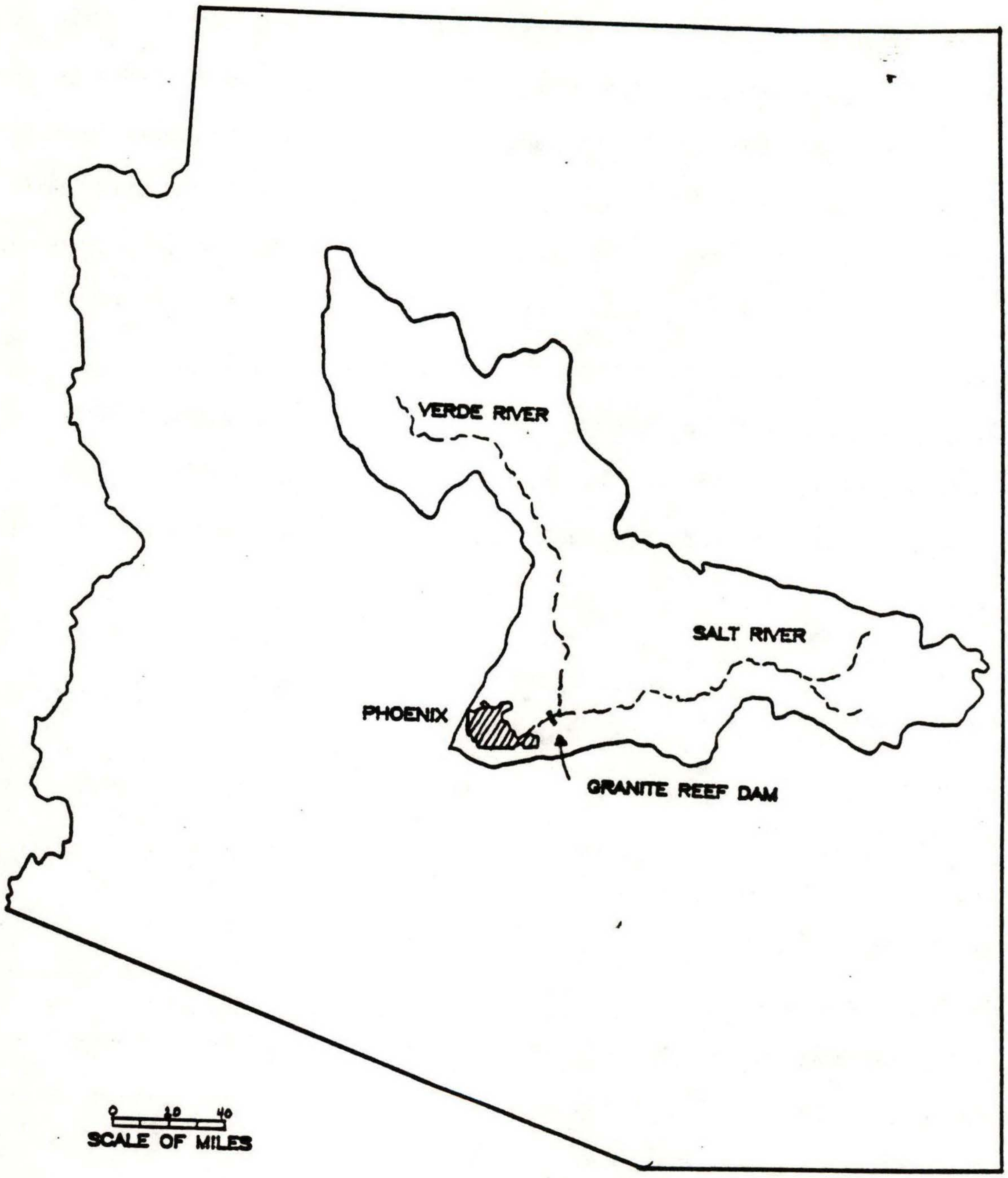


FIGURE 2. SALT AND VERDE RIVER WATERSHED

Hills line the basin. The major tributaries are Sycamore Creek, Oak Creek, Beaver Creek, West Clear Creek, Fossil Creek, and the East Verde River. Below the tributaries, the river empties into Horseshoe and Bartlett Lakes, where it is stored for use downstream. The Verde then continues through the Fort McDowell Indian Reservation to its confluence with the Salt River within the Salt River Indian Community. A stream guage located 2.5 miles upstream from its mouth has measured the discharge of the river at an average of 492,700 acre-feet per year (US Geological Survey, 1982).

Groundwater resources can usually be found at depths of less than 200 feet along the Verde River. On valley slopes water is found at depths of 200 to 500 feet (Arizona Office of Economic Planning and Development, 1977).

B. Economic Setting

The uses of water from the Salt and Verde watersheds represent every contributing sector to the Arizona economy: irrigated agriculture, municipal and industrial, mining, electric power production, recreation, and wildlife.

Upper Salt River Valley

The Salt River Valley above Granite Reef Dam is made up primarily of portions of the San Carlos Indian Reservation, the Fort Apache Indian Reservation, and the Apache and Tonto National Forests. Most of the private land in the watershed is found in the vicinity of Globe. The remainder is located along creeks and rivers.

Sheep and cattle ranchers utilize nearly the entire area for grazing purposes. Several large livestock operations are located near Globe.

Copper mining and quarry activity contribute heavily to the economy of the region. A number of open pit mines, mills, and smelters are located in

the Globe-Miami area. Finally, tourism and recreational activity play an important part in the economy of the small communities found in the Salt River drainage area.

The municipal and industrial water needs of the upper Salt River Valley watershed are met with groundwater, with the exception of McNary, which diverts surface water from the North Fork of the White River. Above Roosevelt Dam, somewhat less than 4,000 acres are devoted to agricultural production. Irrigation water is diverted from the White River, Carrizon Creek near Show Low, Cibecue Creek near Chrysotile, and the Salt River. (US Geological Survey, 1983).

<u>Verde River Valley</u>

There are four major communities in the Verde Valley: Camp Verde, Cottonwood, Clarksdale, and Jerome. In 1899, Jerome was incorporated as the fifth largest city in Arizona (Arizona Office of Economic Planning and Development, 1977). At one time, there was a population of 15,000 as a result of mining activity in the area. The mine closed in 1953 and today Jerome is predominantly a retirement community of 420 people (Valley National Bank, 1982). Jerome is also a major tourist and recreation center, with its economy based almost exclusively on these activities (Arizona Office of Economic Planning and Development, 1982c). Jerome's water comes from mountain springs in the Prescott National Forest, some thirteen miles away, and is delivered by a municipal water supplier.

Between 1912 and 1915, a new smelter was constructed east of Jerome near the Verde River, and the town of Clarksdale was born. Clarksdale now has a population of 1512 and is served by groundwater from eleven area wells. The Cottonwood Water Works, a private utility, supplies water to Clarksdale and also to Cottonwood.

In 1879, soldiers from Camp Verde were stationed at an adobe house where Cottonwood stands today. Settlers moved into the area and a community was formed which took its name from a circle of sixteen cottonwood trees near the river. Today Cottonwood has a population of 4,550 people, 26 percent of whom are retired, and serves as a trading center for the Verde Valley (Arizona Office of Economic Planning and Development, 1982b). Besides receiving water through the Cottonwood Water Works, Inc., the town is served by the Clemenceau Water Company.

Camp Verde is the oldest community in the Valley, established in 1865 as a military reservation to protect settlers from Indian raids. Today the population of Camp Verde is 1,125 (Arizona Office of Economic Planning and Development 1982a). Camp Verde receives its water from the Camp Verde Water System, a private utility with eight supplying wells. There have been water quality problems involving arsenic, and the Department of Health Services has shut down several wells (Warskow, 1983).

There are several larger communities outside the Verde Valley that also take part of their water supply from the Verde watershed. Prescott, located on the edge of the watershed, acquires its water supply from area reservoirs and groundwater wells and through a city water system (Warskow, 1983). The municipal water department supplies a population of 24,060.

The community of Payson is located on the East Verde River, a major tributary of the Verde River. The population of 5,068 is supplied with groundwater by United Utilities, Payson System, an investor-owned utility.

The unincorporated community of Sedona/Oak Creek was established in 1902 and has a population of 6,710. It is supplied by the Arizona Water Company, Oak Creek Water Company No. 1, and Big Pauk Water Company (Arizona Office of Economic Planning and Development, 1983).

The other upstream water users in the Verde Valley are small irrigation districts. The Chino Valley Irrigation District is located near the headwaters of the Verde River on either side of state highway 89 northeast of Prescott. The District has water rights to 2,500 acre feet of surface water from Watson Lake (1916) and Willow Creek Reservoir (1935) (Water Resources Research Center, 1980). In 1982, about half of the land in the district was irrigated. Alfalfa and corn were the primary crops.

The Cottonwood Ditch Association is an agricultural water company which maintains a dirt canal for delivering Verde River water to farmers. The Association was formed in 1947, but the first water right dates back to 1877. Eight thousand acre-feet of water are applied each year to approximately 880 acres of alfalfa, pasture, vegetables, and corn (Water Resources Research Center, 1980).

During 1978, a committee attempted to organize twenty-seven ditches in the Verde Valley into one water users association which would have included 6,000 to 10,000 acres within its boundaries. The Verde Valley Water User's Association was not successful, perhaps because the effort involved over 20,000 land-owners (Warskow, 1983).

Today's mining activities currently involve the production of cement by the Phoenix Cement Company in Clarksdale, and the mining of small amounts of "deposited" type minerals such as gypsum and dolomite.

Tourism and outdoor recreation provide the primary economic activity in the valley today. Three national forests, a wilderness area, three state parks and historical sites and two national monuments found in the watershed make this a popular area. There is also a growing interest in the area as a retirement location, and population is expected to double in the next fifty years.

The main agricultural activity is livestock, mostly cattle. There are a number of ranches in the vicinity of the Verde River that depend on national forest lands for yearlong grazing (US Forest Service, 1981b). Stock ponds, springs, and river water are utilized as sources for stock water.

Surface water is used primarily for recreation and irrigation, but surface-water use is limited in the area because of downsteam water rights. About 12,000 acres in the Valley are irrigated; mostly on level areas near Camp Verde and adjacent to the Verde River. The amount of surface water consumed by irrigated crops is estimated to be 31,000 acre-feet per year (Owen-Joyce and Bell, 1983). Forage, permanent pasture, and small grains are the primary crops.

Groundwater is presently used as the principal source of water for domestic and municipal uses; annual draft on the groundwater system is estimated to be 8,000 acre-feet, with less than 10 percent used for irrigation (Owen-Joyce and Bell, 1983).

<u>Salt River Valley/Phoenix</u>

Agricultural and M&I water use in the Salt and Verde watersheds is small in relation to use in the Phoenix metropolitan area and the surrounding irrigation districts. This area has developed as an industrial and distribution center for the Southwest. Services, retail trade, manufacturing and government were the most important employment sectors in Maricopa County in 1982 (Maricopa County Planning Department, 1983).

Although agriculture is not a significant employer in the area, it is important in terms of the gross income it generates. In 1980, agriculture ranked eighth as an <u>income source</u> (cash receipts from sales of crops and livestock) for Maricopa County residents. Crops and livestock contribute

almost equally to total agricultural income (Maricopa County Planning Department, 1983). Over 750 square miles of the county (8%) are devoted to agricultural land uses, with over 60 percent of the agricultural land located just outside the Phoenix metropolitan area. One half of all agricultural lands are used to grow cotton. Other major crops grown are, wheat, alfalfa, hay, grains, vegetables, and citrus.

There are two kinds of water resources in Maricopa County--groundwater and surface water. Groundwater, the largest supplier, accounts for 70 percent of all water used in Maricopa County. The County's reliance on groundwater has led to drawdown of the water table. The water table has dropped from 50 to 400 feet in many locations, although in some areas (particularly within the Salt River Project area) the water table has risen in recent years. The Salt-Verde system supplies 93 percent of the total surface water. In much of the area, surface water and groundwater supplies are used conjunctively to provide a firm supply.

Maricopa County has an estimated population of 1.6 million people (Maricopa County Planning Department, 1983). The county's population is expected to reach 2.6 million by the year 2000 largely as a result of continued in-migration. Nearly all of this projected growth is expected to take place in the Phoenix metropolitan area. Although agriculture currently uses 70 percent of available water supplies, the greatest increase in demand for water supplied by the Salt-Verde River system is expected in the Phoenix metropolitan area as agriculture is replaced by residential and industrial uses.

In the ten year period preceding 1982, urban development resulted in the conversion of 123 square miles of agricultural land in Maricopa County. Demand for land is expected to result in the additional conversion of 200 square miles of land in Maricopa County by the year 2000, representing a 25

percent reduction in agricultural land use in the county. Approximately 10 square miles of vacant desert land is also expected to be converted to urban uses (Maricopa County Planning Department, 1983). The Salt River Project area, for example, is being urbanized at a rate of 4,000 to 7,000 acres a year. SRP predicts that by the year 2000, 80 percent of the SRP area will be urbanized, and that by 2034 the entire project area will be urbanized (Salt River Project, 1982a and 1985).

C. Legal-Institutional Setting

In Arizona, two separate bodies of water law have developed. Surface water is governed by the doctrine of prior appropriation, while the use of groundwater is governed by a system of "grandfathered" rights established by the 1980 Groundwater Management Act.

State Water Code

The doctrine of prior appropriation developed in response to the arid environment of the West. It is designed to protect a water user's interest in a scarce supply by establishing a priority of right based on the date of appropriation. Should a shortage occur, older appropriators have the prior and superior right to the exclusion of junior appropriators.

The right to appropriate water was affirmed by the first legislature of the Territory of Arizona in 1864 through the Bill of Rights in the Howell Code. Here it was declared that all streams, lakes, and ponds of water capable of being used for navigation or irrigation were public property, and the right to appropriate them exclusively to private use was denied, except under legislative regulation (Terr. Arizona Bill of Rights, Art. 22,1864). Waters subject to appropriation in Arizona now include ". . . waters of all sources, flowing in streams, canyons, ravines or other

natural channels, or in definite underground channels, whether perennial or intermittant, flood, waste or surplus water . . . ." (ARS 45-131).

Persons who appropriate such public waters acquire a vested property right in their use, not in the water itself. This usufructuary right is limited to a beneficial use. Beneficial use is the "basis, the measure and limit to the use of water" (Arizona Const., Art 17, Sec. 2). In 1974, beneficial use was defined by statute to "include, but is not limited to, use for domestic, municipal, recreation, wildlife, including fish, agriculture, mining, stock watering and power purposes" (ARS 45-180).

In the vast majority of cases, a surface water right is appurtenant or attached to the land to which the water rights were originally granted. However, the territorial government granted water rights to some people on the basis of shares of water, and those shares can be bought and sold. In some instances, the transfer of water right without loss of priority is allowed, subject to certain limitations and conditions (ARS 45-172).

The exclusive method of acquiring an appropriation right is now through application for a permit to the Arizona Department of Water Resources (DWR) If the proposed use of the water is beneficial, is in keeping with the public interest and safety, and does not interfere with existing rights, a Certificate of Water Rights is issued to the applicant.

Any person or agency proposing to build a reservoir must obtain a permit from the Department of Water Resources. In addition, any person proposing to use the water stored in such reservoir must file an application for secondary permit. The applicant must show, "That a written agreement has been entered into with the owners of the reservoir for a permanent interest in the reservoir sufficient for the purposes set forth in the application" (ARS 45-151).

Rights to the use of surface water have also been established by court law through decrees rendered during the settlement of specific disputes.

Kent Decree

In 1867, construction was begun on the first modern irrigation canal in the Phoenix area. Twenty years later, over 100,000 acres were under cultivation. The landowners in the Salt River Valley formed the Salt River Valley Water Users' Association in 1903 to insure that rights to water stored by Roosevelt Dam would be equitably distributed. However, by 1905, when construction began on Roosevelt Dam, concern over the loss of water rights led to the adjudication of surface rights, dating from 1869 through 1909, to water from the Salt and Verde Rivers.

On March 1, 1910, Judge Kent presented the Kent Decree, which established relative water rights to surface water supplies and set up the principle of normal flow rights. Land which had been in continuous cultivation since its first irrigation (referred to as Class A land), beginning sometime during 1869 through 1909, was decreed to have a right to the unregulated flows of the Salt and Verde Rivers. The relative distribution of the normal flow between water right holders was based on the date of appropriation, whether accomplished by diversion and beneficial use or by posting of notice to appropriate. Class B land is land which had been in discontinuous production, and Class C land is land which had not been cultivated as of 1909. (See also Benson vs. Allison, U.S. vs. Haggard, and Arlington Canal Company vs. Simpson for additional information on the establishment of Arizona water rights.)

In addition to the landowners in the Salt River Valley, the Kent Decree also allocated water for use by the Indians of the Salt River and Fort McDowell Reservations. While the Kent Decree set certain Indian water

rights, the Indians do not regard this as a final determination of their rights. Both reservations also claim federally reserved rights.

Water rights of the Upper Verde River lands (e.g., the Verde Valley) and the pumpage of groundwater in the Salt River Valley were not covered by the Kent Decree. Judge Edward Kent found that there was not sufficient irrigated acreage present in the Verde Valley to interfere with prior rights in the Salt River Valley.

Colorado River Basin Project Act

A complex body of law has developed which apportions and regulates the use of water from the Colorado River. The U.S. Supreme Court, in Arizona v. California (373 US 546, [1963]), confirmed Arizona's right to 2.8 million acre-feet of the first 7.5 million acre-feet of Colorado River water available for consumptive use by the Lower Basin States. In 1968, the Colorado River Basin Project Act (P.L. 90-537) authorized the Central Arizona Project (CAP), which would enable construction of the conveyance and storage facilities necessary to deliver a portion of Arizona's entitlement.

The Colorado River Basin Project Act also required that Arizona designate one official agency with which the Secretary of the Interior could contract for repayment of CAP construction and delivery costs. This agency, in turn, could enter into contracts with the ultimate users. The Central Arizona Water Conservation District (CAWCD) was formed in 1971 to carry out this function.

The Central Arizona Project will bring Colorado River water via aqueducts to the Phoenix area in 1985. Northern Arizona communities, including Indian tribes located along the Verde River, have also been tentatively granted a share of CAP water. Allocations tentatively granted

to Indian tribes and major municipalities in the Verde and Salt watersheds are shown in Tables II-1 through II-3. Allocations of CAP water could be accomplished through water exchanges with the Salt River Project (US Forest Service, 1981b). Verde Valley users would take more water from the Verde River and then pay SRP a proportionate share of compensation for CAP water brought into Phoenix from the Colorado River by the CAP. Prescott, Cottonwood and Camp Verde could divert water directly from the Verde River while Pine and Payson could divert water from the East Verde or its tributary, Pine Creek (USDA Forest Service, 1981b).

The CAP allocation for Phoenix varies from 54,000 acre-feet per year in 1985 to 116,000 acre-feet per year in 2034. By 1990, deliveries to entities in Maricopa County are expected to be approximately 500,000 acre-feet per year, representing 15 percent of water supplied from all sources.

Deliveries to the Phoenix area are scheduled to begin in 1985. Pinal County will receive water in 1986 or 1987 and Pima County in 1991. Colorado River water will be used primarily to supplement existing water supplies and to reduce groundwater pumping. According to Wes Steiner, director of the State's Department of Water Resources, CAP will increase the dependable water supply by almost 50 percent (The Department of Water Resources defines dependable as the amount of water that can be withdrawn annually without long-term lowering of storage levels in either surface or groundwater reservoirs). Dependable supplies include available surface water, natural groundwater recharge, and renewable imports to the area (Arizona Department of Water Resources 1984). Also according to Steiner, the CAP "has the capability of relieving groundwater overdraft [in Pima, Pinal and Maricopa Counties] by approximately two-thirds. The other third has to come from conservation -- changing our types of water use in the state" (Brown, 1983).

Table II.1. Population Projections and Tentative Central Arizona Project Allocations for Selected Cities, Towns and Indian Communities.

Maricopa County Municipal and Industrial Water Users	CAP Allocation (Acre Feet per year) Average Over 50 yr life of project
Municipal Subtotal	288,397
Phoenix only	116,239
Power[1]	43,239
Recreation Subtotal	989
Other[2]	39,096

Upper Verde Valley Communities	Population Projections[3] 1985	2034	CAP Allocation (50 year period) Acre feet
Camp Verde	4620	13,550	38,000-45,000
Clarkdale		5,950	
Cottonwood Water Col	4925	17,385	33,000-45,000
Jerome		965	
Pine-Payson	8095	30,355	111,000-132,000
Prescott	21,120	49,515	189,000-232,000
Salt River Valley Communities			
Globe	8,785	25,000	82,000-91,000
Miami-Claypool	7,310	11,960	50,000-61,000
Indian Communities[4]			
Camp Verde	650	1,580	52,000-54,000
Ft. McDowell	442	854	185,000-191,000
Gila River	10,538	17,390	4,250,000-7,532,000
Salt River	3,472	5,424	393,000-580,000
Tonto Apache (Payson)	69	77	5,000
Yavapai (Prescott)	82	137	21,000-22,000

(Source: US Bureau of Reclamation, CAP Allocations Environmental Impact Statement, 1982).

[1] Arizona Public Service and Salt River Project
[2] Phoenix Memorial Park-5 acre feet per year, State Land Dept.-39,091 acre feet total
[3] Projection for 2034 based on revised estimates from Bill Towler, NACOG.
[4] Allocation is for irrigation on the Salt River Reservation. Allocations to the Salt River, Gila River, and Camp Verde communities was made on the basis of "presently developed acreage," while allocations to the Tonto Apache and Yavapai communities were made on the basis of "tribal homeland."

Table II.2. Population Projections and Tentative Central Arizona Project Allocations for Upper Verde Watershed Communities.

Entity[1]	Population 1985	Projections[2] 2034	Schedule of Demand in Acre Feet in Year 2034
Camp Verde	4620	13,550	1,443
Cottonwood Water Co.	4925	17,385	1,789
Payson	8095	30,355	4,995
Prescott	21,120	49,515	7,127

[1]Includes Arizona Department of Water Resources recommendation that municipal subcontractors be allowed to contract for up to the amount of water identified for the year 2034 at any time during the contract repayment period.

[2]Projection for 2034 based on revised estimates from Bill Towler, Northern Arizona Council of Governments.

Source: US Bureau of Reclamation, Final Environmental Impact Statement, Central Arizona Project: Water Allocations and Water Service Contracting, 1982.

Table II.3. Population Projections and Tentative Central Arizona Project Allocations for Indian Communities of the Salt-Verde Watersheds[1)]

Indian Community	Population 1985	Projections 2034	CAP Allocation in Acre Feet in Year 2034
Camp Verde	650	1,580	1,200 I[2)]
Ft. McDowell	442	854	4,300 T
Gila River	10,538	17,390	173,100 I
Salt River	3,472	5,424	13,300 I
Tonto Apache (Payson)	69	77	128 T
Yavapai (Prescott)	82	137	500 T

1)During shortages, CAP deliveries are reduced until exhausted to all miscellaneous and non-Indian agricultural uses, then 25 percent of the Gila Tribe and 10 percent of other Indian agricultural uses are reduced until exhausted. Finally, the Indian agricultural uses are reduced pro-rota with no more than 510,000 acre-feet of M&I uses, based on amount of water actually delivered to each entity in the most recent past year of fuel deliveries to these entities.

2)T = allocation for tribal homeland purposes; I = allocation for irrigation.

Source: US Bureau of Reclamation, Final Environmental Impact Statement, Central Arizona Project: Water Allocations and Water Service Contracting, 1982.

The Bureau of Reclamation's estimates of average Colorado River water availability for CAP use vary between 742,000 acre-feet per year to 1,523,000 acre-feet per year. The average of all its supply scenarios is 1,144,000 acre-feet per year. In assessing the environmental effects of various CAP allocation alternatives, however, the Bureau and the Arizona Department of Water Resources agreed to use an average Colorado River water availability of 1,298,000 acre-feet per year (US Bureau of Reclamation 1982). This agreed-upon estimate was also based on the assumptions that water would be developed on the Salt and Verde Rivers by the functional equivalent of Orme Dam (later called Confluence Dam) and on the Gila River by Buttes and Hooker Dams. All were congressionally authorized features of the CAP in the Colorado River Basin Project Acts.

The construction of Orme Dam at the confluence of the Salt and Verde Rivers, however, would have resulted in the inundation of a large part of the Fort McDowell Indian Reservation and required the relocation of the Fort McDowell Community. The Community strongly opposed both its relocation and the inundation of sacred land. Because of this and expressed environmental concerns about the loss of prime wildlife habitat, strong opposition to Orme Dam developed. As a result, the Central Arizona Water Control Study (CAWCS) was initiated in July of 1978 to develop and evaluate alternatives for regulatory storage of CAP water in central Arizona and for flood control of the Salt and Gila Rivers through the metropolitan Phoenix area. In addition, Safety of Dams (SOD) was incorporated as an objective into the evaluation process as a result of the Reclamation Safety of Dams Act (P.L. 95-578).

In November 1981, the Secretary of the Interior labeled "Plan 6" as the agency-preferred action. Plan 6 includes a New Waddell Dam to replace

the existing Waddell Dam on the Agua Fria River for regulatory storage purposes and incidental flood control. Stewart Mountain Dam on the Salt River would be modified or replaced for dam safety only. A new or enlarged Roosevelt Dam would be constructed on the Salt River, and Cliff Dam would be constructed on the Verde River between the existing Horseshoe and Bartlett Dams. Both Roosevelt and Cliff dams would provide flood control, additional water conservation, and SOD.

Under Plan 6, the CAP yield would be increased by 137,600 acre-feet per year through regulatory storage at New Waddell Dam, dual use of the sediment pool at Roosevelt Reservoir, and new conservation space at Cliff Dam. In this instance, the environmental impact statement assumed that the average annual water supply to be delivered through the CAP without regulatory storage would be 1,006,000. (This number assumes that CAP aqueducts would operate essentially as a demand system, that safety dams studies would continue, and that Butte and Hooker Dams or equivalents would be built as CAP authorized control structures) (US Bureau of Reclamation 1984). Projected average annual CAP water yield for Plan 6 is 1,172,000 acre-feet per year (US Bureau of Reclamation, 1984).

Under the allocation plan, 85 municipal and industrial users in Arizona are tentatively expected to receive 638,824 acre-feet per year, with Phoenix receiving approximately 116,000 acre-feet. Twelve Indian tribes or communities have been allocated 309,828 acre-feet per year for irrigation or for maintaining tribal homelands. The remaining supply would be available for use by 23 irrigation districts or farming operations. (Non-Indian agricultural allocations are shown in Table II-4). During shortages, CAP deliveries would be reduced until exhausted to all miscellaneous and non-Indian agricultural uses, then 25 percent of the Gila tribe and 10 percent of other Indian agricultural uses would be reduced

Table II.4. CAP Water Allocations for Non-Indian Irrigation[1)]

Entity	County	Percent of Supply Available 1985 (%)	2005 (%)	2034(%)
Arcadia Water Co.	Mar.	0.13	0.14	0.15
Avra Valley Assoc.	Pima	3.69	3.84	4.21
Central Arizona I.D.[2)]	Pinal	18.01	18.73	20.55
Chandler, Heights I.D.	Mar.	0.28	0.28	0.30
Cortaro-Marana	Pima	2.14	2.05	1.99
FICO	Pima	1.39	1.44	1.58
Harquahala Valley	Mar.	7.67	7.98	8.75
Hohokam I.D.	Pinal	6.36	6.61	7.25
La Croix	Mar.	0.04	0.04	0.05
Maricopa-Stanfield I.D.	Pinal	10.48	21.30	23.35
Marley, Kemper Jr.	Mar.	0.04	0.04	0.05
McMicken I.D.	Mar.	7.28	5.60	2.61
MCMWCD #1	Mar.	4.66	3.37	2.88
New Magma I.D.	Pinal	4.34	4.52	4.96
Rood, W.E.	Mar.	0.04	0.04	0.05
Roosevelt I.D.	Mar.	2.61	2.72	2.98
RWCD	Mar.	5.98	5.92	4.84
SRP	Mar.	2.97	3.05	0.00
San Carlos I.D.	Pinal	4.09	4.25	4.66
San Tan I.D	Mar.	0.77	0.80	0.86
Tonopah I.D	Mar.	1.98	2.06	2.26
U.S. Forest Service		0.22	0.23	0.25
		100.00	100.00	100.00

1)When available non-Indian irrigation shares CAP Water according to the tested percentages.

2)I.D. = Irrigation District

Source: US Bureau of Reclamation, Final Environmental Impact Statement, Central Arizona Project: Water Allocations and Water Service. 1982.

until exhausted. Finally, the Indian uses would be reduced pro-rata with no more than 510,000 acre feet of M&I uses, based on the amount of water actually delivered to each user in the most recent year of full deliveries (U.S Bureau of Reclamation 1982). Water allocatted, but not contracted for, will revert back to the state and will be reallocated among applicants from the three participating counties. In April of 1984, the Secretary of the Interior approved the final impact statement and the Plan 6 alternative, but delayed for six months a decision on the most controversial aspect of the plan, building of Cliff Dam.

Gila River Adjudication

Water rights in the Gila River drainage system, which includes the Salt and Verde rivers, are now in the process of adjudication. An adjudication is a court determination of the status of all rights to use water from a river system and source. This adjudication will determine the extent and priority of all appropriative water rights and all water claims based on federal law.

The Department of Water Resources assists the court by notifying all property owners in the watershed, and tabulating, mapping, investigating, and verifying the statement-of-claimant forms once they are submitted. The Department also investigates water supplies and compares them to amounts claimed. Once the DWR submits its report to the superior court, a special master is appointed. The master takes testimony and submits his findings to a judge who has been appointed by the state supreme court (Arizona Department of Water Resources, 1981).

Shortly after basinwide adjudications were initiated in state court by non-Indian water users, Indian communities--and the United States on behalf of the Indians--filed actions in federal court requesting adjudication of

water rights. The tribes were asking for removal of state adjudications to federal court, and for declaratory and injunctive relief preventing any further independent federal determinations of their water rights. This suit was dismissed by the district court in favor of state adjudications pursuant to the McCarren Amendment, which waives the sovereign immunity of the United States in comprehensive state water rights adjudications.

On appeal, the Ninth Circuit Court of Appeals overruled the holding of the district court in February 1982. The basis for the Ninth Circuit's decision was that Arizona was a "disclaimer" state and that disclaimer removed from the state's jurisdiction the adjudication of Indian water rights. The court of appeals held that the Enabling Act under which Arizona was admitted to statehood (36 Stat. 557, 1910) and the Arizona Constitution (Art. 20, 94.) disabled Arizona from adjudicating Indian water claims. The case was remanded to the district court to determine whether Arizona nevertheless "properly asserted jurisdiction pursuant to Public Law 280" (668 F. 2d at 1098, sec. 668 F.2nd at 1102).

The US Supreme Court granted certiorari to hear the San Carlos case. The fundamental issue, decided by the Court on July 1, 1983, related to the jurisdiction of state courts to adjudicate Indian water rights (_Arizona et al. v. San Carlos Apache Tribe of Arizona et al._, 103 S. Ct. 3201). The 6 to 3 majority decision in _San Carlos_ held that the disclaimer provision in Arizona's enabling act did not prohibit Arizona from adjudicating Indian water rights. The Court also held that if comprehensive, statewide adjudications were underway the process may be an acceptable forum for determining Indian water rights.

The Arizona Department of Water Resources is now proceeding with its adjudicative efforts. This action is significant to water management in Arizona primarily for two reasons. First, Indian water claims, which are

discussed in the following section, will be included in the adjudication. Establishing Indian water rights will facilitate long-range water planning by eliminating the uncertainty of these demands. Second, the problem of incomplete, uncertain or inaccurate descriptions of water rights will also be remedied by the administrative function carried out by DWR as an agent of the court. Once the identity, location, purpose, priority, place of use, and quantity are determined, water administration and planning will become more efficient. It could also facilitate the development of a water market and more efficient water transfers or exchanges.

Indian Water Rights

Although Indians living on reservations in Arizona represent less than 6 percent of the state's population, Indian Reservations encompass over 27 percent of the state's land (Arizona Water Commission, 1977). Allocation of future water supplies could change considerably as a result of quantifying Indian Winters Doctrine rights and aboriginal rights.

The Winters Doctrine, so called because of its origin in the Supreme Court case Winters v. United States, affirms the power of the federal government to reserve sufficient waters to satisfy purposes for which the lands were reserved (207 US 564 [1908]). In contrast to aboriginal rights, which are based on established prior uses, Winters rights are measured by the potential for water use on the reservation.

Since Winters, other court decisions have established the nature of the reserved water right. It is a private right which cannot be lost by nonuse or legal action, and which is held in trust by the United States for the benefit of the Indians. The right is not dependent upon application of water to beneficial use. Winters rights date to the creation of the

reservation and are for an unspecified quantity of water sufficient to supply present and future needs.

In the case of Arizona v. California, the Supreme Court established the measure of reserved rights for five tribes located along the lower Colorado River as the amount of water necessary to irrigate the "practicably irrigated acres" on the reservation. The Court said:

> "the Master's choice of irrigable acreage as a measure was based on the conclusion that it provided an estimation of the amount eventually needed to make the otherwise arid lands productive. The Indians' actual use of the water remains unrestricted. Practicable irrigable acreage, then, is a rough measuring stick, a tool toward an informed equitable estimate of the Indians' needs, both present and future" (373 US 546, [1963]).

This standard of quantification is not appropriate for all reservations but constituted the law for the reservation under consideration.

Quantification of Indian reserved water rights in the Salt and Verde Rivers watersheds could have a considerable effect on current water users in the area since most land in these watersheds is encompassed by Indian reservations or is under Forest Service management. Both the Salt River Community and the Fort McDowell Reservation claim federal reserved rights to water in addition to that now supplied by groundwater pumping and SRP. If Indian claims to additional water are satisfied even in part, water would have to be transferred from existing non-Indian users or new sources of supply would have to be developed.

At hearings held by the US Senate Select Committee on Indian Affairs, Arizona's position regarding Indian water claims was set forth by Wesley E. Steiner, executive director of the Arizona Water Commission. He said:

> . . . the rights of the Salt River and Fort McDowell Reservations to waters of the Salt and Verde river were established in the case of Abbot v. Hurley--the Kent Decree--in a general adjudication of water rights in the lower reaches of those two rivers.
>
> It is our belief that the Kent and Gila decrees recognized the Winters doctrine and constitute an adjudication of the surface water rights of the Salt River, Fort McDowell, and Gila Indian Reservations to the waters of the Salt, Verde, and Gila Rivers.

With regard to groundwater Steiner said:

> Certainly it was not the intent in the formation of any of the five central Arizona reservations to reserve more water than could be diverted from local streams to support an agricultural economy. There was no knowledge of the groundwater resource and hence they did not figure in either the intent or in the reservation of water.

Steiner also stated that the reserved rights of the Indians were limited ". . . to the supplies that could be developed, transported, and applied economically at the time that the reservations were formed" (US Senate, 1975). Claims of the Indians greatly exceed limits suggested by Steiner.

Groundwater Law

The 1980 Groundwater Act gives the Department of Water Resources significant power to manage groundwater. The Act initially established four Active Management Areas (AMAs) that generally correspond to groundwater basins where the groundwater overdraft has been most severe. In these areas, the Code established a program for reducing groundwater withdrawals, a requirement of an assured water supply for new development, a halt to the development of new irrigated farmland, and a management goal of "safe-yield" by January 1, 2025 or sooner. Safe yield is defined by the Code as a "management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn . . . and the amount of natural and artificial recharge" (ARS 45-561).

In order to achieve safe yield, groundwater management plans will be written every ten years. Each management plan will contain a mandatory conservation program for all groundwater users. Agricultural users in an AMA will receive a "water duty" limiting pumping to the minimum of water necessary for crops historically grown in the area. Mines and other industries will be required to use "the latest commercially available conservation technology consistent with reasonable economic return" (ARS 45-564). Per capita consumption reductions will be required of municipal users.

New development in areas where a developer cannot show an assured water supply is effectively prohibited. An assured water supply means sufficient ground or surface water supply of adequate quality to satisfy the proposed use for at least 100 years. Unless the Department of Water Resources finds that an assured water supply exists, the State Real Estate Department may not approve the property report, nor may the local governing body approve a subdivision plat. Anyone offering subdivided land for sale within the service areas of cities, towns, and private water companies with assured supplies is exempt from applying for certificate. If a city, town, or private water company has received an allocation of CAP water, the service area and extensions of the service area are all deemed to have an assured supply until December 31, 2000. Thereafter, the determination is subject to review by the director of DWR.

Beginning in the second management period, the Code provides for the assessment of water quality considerations, as indicated by the following management phases of the Groundwater Management Code:

1980-1990: First Management Period.

*Irrigation water duty
*Municipal and Industrial conservation program

1990-2000: Second Management Period.

*Augmentation Program
*Cooperation with Department of Health Services

2000-2010: Third Management Period.

*Demonstration of assured water supply
*Possible purchase and retirement of farmland

2010-2020: Fourth Management Period

January 1, 2025: Safe-yield

III. POTENTIAL BENEFICIARIES OF INCREASED STREAMFLOW

A. The USDA Forest Service

This study assumes that the increased water yields will result from vegetative modification practices used on lands managed by the USDA Forest Service. The Forest Service maintains that the United States:

> has retained the power to reserve from future appropriation under State Law the unappropriated nonnavigable waters on the public domain, as well as the power to utilize them itself and to provide for their utilization by others. The reservation of the unappropriated rights to use the waters on public lands results from the withdrawal or reservation of such lands for a particular Federal purpose . . . (Forest Service Manual 1981, Sec. 2541.01).

The extent of federal reserved rights is, however, limited to the original purposes for which the reservation was made. The U.S. Supreme Court stated in United States v. New Mexico that "(w)here water is only valuable for a secondary use of the reservation, however, there arises the . . . inference . . . that the United States would acquire water in the same manner as any other public or private appropriator" (438 US 696,701 [1978]).

The Forest Service thus maintains a policy of "caution and reasonableness in its deliberate use of water," one that stresses cooperation with the states in water rights matters. In fact, the Forest Service tries to quantify and inform the states of its existing and future water uses. Allocation of water and water rights outside the uses for which the national forests were established is the function of the state regulatory agency.

Present and projected water needs on Forest Service lands are very small when compared to potential water yields from such lands.

B. Upper Verde River Valley

Among all users in the Valley, 31,000 acre-feet of surface water is consumed by irrigated crops each year and 8,000 acre-feet of groundwater is withdrawn each year primarily for municipal and domestic use (Owen-Joyce and Bell, 1983). Upstream rights are, for the most part, senior and the total usage is relatively small. For these reasons, water users in the Upper Verde Valley are not considered significant potential beneficiaries of any increased water predicted to result from vegetative modification.

C. Salt River Valley/Phoenix

The Salt River Project (SRP) was the first multipurpose project authorized under the Reclamation Act of 1902. It is a nonprofit organization which incorporates the Salt River Valley Water Users' Association and the Salt River Project Agricultural Improvement and Power District.

The District is a political subdivision of the State of Arizona and operates the Project's electric facilities, which supply electricity to residential, commercial, industrial and agricultural users. The district delivers electricity to approximately 400,000 customers in parts of Maricopa, Gila, and Pinal counties. In the year ending April 30, 1983, 11.5 percent of the power distributed by the district came from hydroelectric facilities located at each of the four dams on the Salt River. The other sources of power are coal and gas. Electric operating revenues were 645.2 million dollars for fiscal year 1983, which represents 99 percent of the Project's total revenues (Salt River Project, 1983).

The Association is a nonprofit Arizona corporation responsible for the administration of the water rights of its shareholders. In this capacity, the Association maintains a high level of interest in the Forest Service's

management of the 13,000 square mile of watersheds on the Salt and Verde Rivers. As agent for the District, the Association operates and maintains a 1,300 mile transmission and distribution system that provides water for agricultural, industrial, and municipal uses in the Project's 250,000 acre service area. Project service lands lie on both sides of the Salt River to the north and east of its confluence with the Gila River. Revenues from water deliveries in fiscal year 1983 amounted to approximately 7 million dollars. Expenses exceeded revenues by approximately 8 million dollars in fiscal year 83 and 13 million dollars in fiscal year 1982. Portions of the revenues from the Project's electrical operations help to support the water operations.

The Salt River Project primarily delivers water to Association member lands within the Project's boundaries. But because of a number of contracts and agreements, the Project also delivers water for use on non-member lands located within the Project boundaries and water for use on lands located outside the Project boundaries (off-Project). A discussion of these water users and the nature and extent of their water use follows.

Project Deliveries to Member Lands

At the present time, approximately 41 percent (98,546 acres) of the land within Project boundaries is in agricultural production, while 59 percent (139,626 acre) is urbanized (Salt River Project 1983). Deliveries to agriculture account for 62 percent of the present water demand. This share will continue to decrease as new urban development occurs. Agricultural land within Project is being converted at the rate of 4,000 to 7,000 acres per year (Salt River Project, 1982). When land use changes from agriculture to urban uses, the city of jurisdiction usually assumes the payment of the SRP assessment and then, acting as an agent for the

landowner, receives, treats, and delivers the land's share of water. Cities under domestic contract with SRP to receive Project water include: Phoenix, Mesa, Glendale, Tempe, Scottsdale, Chandler, Gilbert, and Peoria. In addition, water is delivered for urban irrigation, which includes parks, schools, churches and residential purposes.

Three classes of water are delivered to Project land: normal flow water, stored water, and developed water. The principle of normal flow rights was established by the Kent Decree handed down in 1910. (A discussion of the Kent Decree can be found in Chapter II).

Normal flow refers to the flow of water in the river at its varying stages, without any storage facilities. Only land in continuous cultivation since its first irrigation in any year from 1869 to 1909 was decreed normal flow rights. The amount of normal flow water available for use on a specific piece of land depends on the amount of water flowing in the river and the priority of appropriation, as specified in the Kent Decree.

Unused normal flow and surplus water--water over and above the normal flow of the river, that is stored by reservoirs in the Salt/Verde system--constitutes the second class of water. Stored water is available to Project landowners upon payment of an annual assessment fee. Each acre of land is entitled to two acre-feet per acre and an equal share (by acre) of any additional water. The amount of additional water available is determined--based on the amount of water in storage at that time--prior to each irrigation season by the SRP Board of Governors.

Developed water refers to groundwater supplied by SRP wells. This is the most expensive class of water delivered by the Project and can be acquired, if and when needed, by landowners who purchased a pump water right. Pump water rights were offered for sale by the SRP to all owners of

on-Project land in 1929 and again in 1948. Although these rights are appurtenant to all lands within the Project, only those lands which are shareholders in the cooperative pump program are entitled to delivery of this water by the Project. Since 1977, there has been a moratorium on new lands joining. Pumping costs for developed water are calculated every month. There are also private wells located on Project land which are used by some farmers to provide supplemental groundwater as needed.

Approximately one-third of total Project water deliveries over the past forty years, about 350,000 acre-feet per year, has been from groundwater. The greatest pumping occurs in the summer months when surface flow is low and demand is greatest.

The SRP is not now supplying, nor has it ever supplied, the full agricultural requirement of the farm lands within its boundaries from surface runoff (Salt River Project 1982):

> "Except for lands having very early water rights (less than 15 percent of the total area within SRP), SRP furnishes only one-half to two-thirds of the water required by the average farm. In November of each year, SRP's Board of Governors allocates water for the following year. The average allocation has been only three acre-feet (af) per year.
>
> Agricultural lands use five to six af per acre. Because that exceeds the amount SRP can supply, the farmer must either pump his own supplemental water or have SRP pump it for him. Specifically, to consistently supply the three af per acre annual water allotment, SRP has had to pump a yearly average of one af per acre. Thus, the dependable supply of surface water for use on lands within the boundaries of SRP is slightly more than two af per acre, which is approximately the amount required today for an urban acre."

<u>Project Operating Rules.</u> The six reservoirs of the Salt/Verde system are operated to maximize hydroelectric production and minimize groundwater pumping. (SRP does not have legal authority for flood control, although flood control is performed as a prudent management response.) (Juetton and Mason 1983). In the spring, the Verde system is lowered to a predetermined

quantity to provide sufficient storage capacity for most spring runoff quantities. Water is then demanded from the storage facilities on the Salt River for electricity generation and water supply during the summer months of May through September. Operation is based on the assumption that the Project will be entering a seven-year drought cycle.

When the decision must be made to waste water in excess of the storage capacity of the Salt system, the Project will make available any of the waste water which can be put to beneficial use. This waste water is offered free of charge to all Project landowners.

Project Deliveries to Non-Member and Off-Project Lands

Delivery of water to land outside SRP boundaries is made to the Salt River Indian Reservation, the City of Phoenix, and to several irrigation districts. The Kent Decree gave the Salt River Indians first priority (over all normal flow rights) to 17,600 acre-feet per year. According to an agreement between the Project and the US Government, the Salt River Indians are also entitled to 20 percent of the positive charge in storage occurring when total Verde storage is between 8,909 and 178,186 acre-feet, up to a maximum credit of 60,000 acre-feet.

The City of Phoenix receives water for use by on-Project, non-member lands and by off-Project lands because of water rights acquired through the construction of the spillway gates on Horseshoe Dam in 1949. The additional storage created by the spillway gates was originally 75,000 acre feet. However, Phoenix accepts 24% of the Verde system sedimentation, which has reduced its storage capacity to 73,032 acre feet. Although the actual space created by the addition of these gates can currently store only 73,032 acre-feet of water, the City can accumulate credits of up to 150,000 acre feet on its gatewater account in any one year. When the water

level in the Verde system is such that Indian and SRP rights have been satisfied, Phoenix gains credit in its account for any additional water added to storage. The additional 76,968 acre-feet of credit accumulates in the Salt system and are subject to loss if any water is spilled from the Salt River portion of the system.

The Roosevelt Water Conservation District has an appropriative water right to 5.6 percent of all water diverted at Granite Reef Dam for Association irrigation purposes. The District acquired this right as a result of lining irrigation canals to reduce the loss of water by seepage. Present operation, however, credits the RWCD with a quantity equal to 5.6 percent of all water diverted at Granite Reef for use on Association lands, regardless of use.

The Buckeye Irrigation District, located southwest of Phoenix, has surface flow rights to the Gila and Salt Rivers which amount equal to 1.1 percent of all water diverted at Granite Reef Dam for Association use. This water is delivered by SRP because Project pumping in the 1920s lowered groundwater levels to the point that surface flow to the Buckeye Irrigation District disappeared.

Two small irrigation districts, the St. John's Irrigation District and Peninsular-Horowitz, are located within the boundaries of the SRP. Both receive pump water through the Project delivery system in lieu of an appropriative water right.

<u>The Phelps Dodge Corporation Agreement</u>. Horseshoe Dam was built in 1946 by the Phelps Dodge Corporation in conjunction with SRP and the federal government. In exchange for water developed by Horseshoe, Phelps Dodge received a one-time credit of 250,000 acre feet of water, to be diverted out of the Black River into Eagle Creek drainage at the eastern edge of the

Salt River drainage area. The water is used in copper production at Morenci.

Phelps Dodge can husband its allotment by replacing the water it uses. To do so, Phelps Dodge pumps water from Show Low Lake into the Salt River by way of its tributaries. In addition, water is diverted into the East Verde River from Blue Ridge Reservoir (Chase 1981). As of November 1983, Phelps Dodge had 169,484 acre-feet remaining of its original allotment.

To compensate SRP for lost power generation, Phelps Dodge also pays a flat rate for every acre foot of water diverted from the Black River. In 1980, this rate was 25 dollars per acre foot.

D. Phoenix and the Salt River Valley Cities

Phoenix

The City of Phoenix, which sprung to life along the banks of the Salt River over 100 years ago, has grown spectacularly. In 1911 it had a population of 13,000; today it has a population of 830,712 and is the ninth largest city in the nation.

Phoenix delivers approximately 150,000 acre feet per year of Salt River Project water to two-thirds of its existing customers. The remainder of the City's water is provided by groundwater supplies and from the surface water credits available to the City from the spillway gates at Horseshoe Dam.

The City's total demand for water in 1980 was 240,000 acre feet. Phoenix water users require approximately 267 gallons, compared to Tucson's per capita use of 160 gallons per day. Forty-eight percent of the City's water supplies are used for residential landscape irrigation. Twenty-six percent is for indoor residential use, 15 percent is for commercial uses, 4

percent is for industrial uses, and 7 percent is for public and semi-public businesses (Rich and Associates, 1983).

Projections of water demand for the Phoenix water system in the year 2035 range at the extremes from a high use estimate of 500,000 acre feet per year to a lower, conservation-oriented estimate of 350,000 acre-feet. A more moderate estimate, which assumes implementation of a conservation program adopted by the City Council, sets demands at 367,000 acre-feet by the year 2005 and 450,000 by the year 2035. In the year 2005, it is estimated that 153,000 acre feet of that demand will come from off-Project, 24,000 from non-member lands, and 190,000 from member lands. (Chase 1983a).

The complicated accounting system for the Phoenix gatewater account is based on the principle that no more SRP water can leave Project lands within the course of a month than is replaced in the same month. City of Phoenix transfer wells and exchange wells enter into the calculations. Transfer wells are City wells located off-Project or on non-member lands which deliver directly into the Phoenix water system. Water from transfer wells is used to directly offset closed system deliveries of Project water to any off-project or non-member lands. Exchange wells are City wells located off-project or on non-member lands (none of the latter currently exist) which deliver water directly into SRP canals. Exchange wells often pump water unacceptable for residential use or from areas of low demand. They are used to directly offset deliveries of project water to any off-project or non-member lands within the city's service area (Chase 1981). Both transfer and exchange wells provide an opportunity for Phoenix to produce groundwater so as to not deplete their gatewater credits (Chase 1983b). Each month the total deliveries of Project water to off-Project and non-member lands in the Phoenix service area is totaled up, and if they exceed the total transfer and exchange, the Phoenix gatewater account is

debited. If they are equal to, or less than, the amounts delivered, no change occurs in the account (Chase 1981).

Arizona Municipal Water Users' Association

The Arizona Municipal Water Users' Association consists of the cities of Phoenix, Glendale, Scottsdale, Tempe, and Mesa. It serves as the principal water lobbyist for the five cities. In the past five years, it has begun to play a larger role in long-range regional water planning and management (McCain 1983).

E. Indian Reservations

Salt River Indian Reservation

The Salt and Verde Rivers converge in the northeast corner of the Salt River Indian Reservation which today encompasses 49,929 acres. Water rights in the Salt and Verde River system were adjudicated in the Kent Decree, with the Salt River Reservation receiving the right to 700 miner's inches (12,670 acre-feet per year) of continuous flow on the north side of the Salt River and 335 miner's inches when available for use on the southside of the river, ahead of all other users and regardless of river stage (Salt River Project, 1985).

The allocation of the Kent Decree, however, left many parcels on the Reservation bone dry, frustrating Indian efforts to create family farm units. As a remedy to this situation, Congress in 1916 directed the Secretary of the Interior "to provide water rights in perpetuity for the irrigation of 631 Salt River Indian allotments of ten acres each . . . "from the waters of the Salt River Project." This amounted to 34,263 acre-feet (US Senate, 1975).

It was not until 1937, when Bartlett dam was constructed as an addition to the Salt River Project, that additional water was made available to the Reservation. However, the agreement between the Secretary of the Interior and the Salt River Project, to carry out the purposes of the Congressional legislation of 1916, provided that no more than 20,000 acre-feet of the storage waters could be delivered to the Reservation in one year, 14,263 acre-feet less than directed (US Senate, 1977). It is estimated that 12,000 acres are now irrigated on the Reservation (US Bureau of Reclamation, 1982). Most are leased by non-Indians, with the Salt River Indian Community irrigating only 260 acres.

The Community claims 190,600 acre-feet of water per year to irrigate 30,575 acres. It currently receives 38,000 acre-feet per year of Salt River Project water (roughly 17,660 plus 20,000) and has been allocated 577,500 acre-feet of Central Arizona Project water (total 50 year delivery). This is an average of 11,552 acre-feet per year (US Bureau of Reclamation, 1982).

The Salt River Community is party to a suit, Salt River Pima-Maricopa Indian Community v. Secretary of the Interior, (no. Civ. 76-796) in U.S. District Court in Phoenix. This is a challenge under the Administrative Procedures Act and the National Environmental Policy Act to the Secretarial order allocating a portion of CAP water. The Community also has a claim against third parties for depleting its groundwater by pumping near the Reservation (US Senate, 1977).

The Community has also filed two federal lawsuits that have been absorbed by the adjudication of the Gila River system. The first suit, against the State of Arizona, is seeking a declaration of the priority of their water rights on the Salt River (Salt River-Pima-Maricopa Indian Community v. State of Arizona). The second suit, against the Secretary of

the Interior, seeks to avoid removal of reservation lands from the service area of the Salt River Project (*Salt River Pima-Maricopa Indian Community v. Secretary of the Interior*).

Fort McDowell Indian Reservation

The Fort McDowell Reservation encompasses 24,680 acres of land and is inhabited by the Fort McDowell-Mohave-Apache (population 349). It is located along both sides of the Verde River and abuts the northeast corner of the Salt River Indian Reservation. The land at Fort McDowell is well suited for grazing. Currently, about 600 acres are being farmed, including an experimental tribal farming project. Irrigation water is diverted from the Verde River and conducted to the Indian land by two ditches. No groundwater development has taken place for Indian agriculture. However, the City of Phoenix maintains a well field on the Reservation (US Bureau of Reclamation, 1982).

Under the Kent Decree, the Reservation received a limited allotment of 390 miner's inches (about 7,000 acre-feet per year) for use on 1,300 acres. The allotment was perhaps limited because of the expectation of the court at the time that the Indians would shortly be removed to other lands. Since the Yavapai were never removed to other lands, the tribe does not regard this allotment of water as a final determination of their rights to the water of the Verde River.

A 1933 soil survey and land classification study classified 2,064 acres of the Fort McDowell Reservation as irrigable (US Senate, 1975), while a 1957 Bureau of Indian Affairs study found 3,300 acres of irrigable land. However, the Bureau of Reclamation has assumed the practical limits of irrigable land to be the 1,300 acres identified by the Kent Decree. At

present, the Indians claim 11,000 acres of irrigable land (US Senate, 1977).

The Tribe claims rights to use any groundwater resources underlying the reservation. The Community claims "a water entitlement for purposes of irrigating all practicable irrigable acres on the reservation, and municipal, industrial and aesthetic uses as well" (US Senate, 1977). They reason that "Limitations which restrict the quantity of water available under the Winters Doctrine to the amount necessary for irrigating irrigable lands would thwart the purpose of reservation establishment in that Indian tribes would in many cases not be able to put their lands to the highest and best use." (US Senate, 1977).

The Community further asserts that its reserved right has an immemorial priority date: "The effect of the establishment of the Camp Fort McDowell as an Indian Reservation was not to confer new rights upon the Indians. In securing aboriginally occupied lands to the Community, the government has recognized and confirmed their preexisting rights. Such rights never having been extinguished in the manner provided by law, they remain intact and undiminished" (US Senate, 1975). They argue that no elimination of aboriginal rights resulted from their removal from the reservation in 1887 because it was involuntary.

The Yavapai Indian Communities

The Camp Verde Indian Reservation is located forty miles east of Prescott and is made up of six parcels of acquired land totalling 715 acres. The economy of the 1,125 member Yavapai-Apache tribe is based on agriculture and wage earning. Both surface and groundwater are now used on the Reservation, with the Verde River as the primary source of irrigation water.

Two additional Yavapai reservations are located in the Verde River watershed. Public Land Order 5422, dated May 31, 1975, provided that an 85 acre tract of land be held in trust by the United States for use by the Payson Community of Yavapai-Apache Indians (US Bureau of Indian Affairs, 1976).

The Yavapai Indians also have a reservation of 1,409 acres in the vicinity of Prescott. There is no agriculture on the Reservation and limited range land. The population of 76 derives income from a creosote pine pole factory and sand and gravel leases (US Bureau of Indian Affairs, 1976).

F. Arizona State Agencies

A number of state agencies have obtained, or are in the process of acquiring, rights to use water in the Verde Valley. The State Land Department has submitted applications for groundwater rights pursuant to the Groundwater Management Act. The Department is also in the process of quantifying and filing for surface water rights on state trust lands. Applications are being made by the Department for any water diversion or impoundment by a leasee of state land for grazing purposes. The amount of water used by state agencies and leasees of state land in the Verde River Valley is small, however, because of the nature and limited extent of their activity in the area. Applications were about forty percent complete on the Verde River as of the fall of 1983 (Young 1983).

The Arizona Game and Fish Department has an interest in preserving instream flows for fish and wildlife purposes on the Salt and Verde watersheds. At present, its main concern is that possible CAP water exchange agreements with upstream Verde River water users could affect river habitats (Carr 1983). If Prescott, for example, were to buy CAP

water in exchange for a right to divert water directly from the Verde River, the Department would seek assurances that any adverse impacts on wildlife would be mitigated.

G. Other Actors

The Bureau of Reclamation

The Bureau of Reclamation has played a key role in the development of Arizona's water resources. The primary statute under which it operates is the Reclamation Act of 1902 and subsequent amendments, along with numerous specific legislative authorizations. The Salt River Project was the first reclamation project to begin construction under this act.

Projects can be undertaken by the Bureau of Reclamation for purposes of irrigation of western arid lands, associated electrical power generation, flood control, fish and wildlife conservation and development, municipal and industrial water supply, and recreation.

The Bureau is responsible for the development and execution of CAP preconstruction and construction programs.

CAWCD and the Corps of Engineers

With the advent of CAP and the possible construction of Plan 6, two new actors have emerged whose interests may be affected by a program of vegetative modification: the Central Arizona Water Conservation District (CAWCD) and the US Army Corps of Engineers.

In July 1971, the CAWCD was formed to act as the central contracting entity for CAP water and to guarantee the repayment of reimburseable CAP costs. If the Bureau of Reclamation (rather than another organization) were to construct and finance Cliff Dam, the additional water would go to the CAP, and the CAWCD could have the responsiblity for repayment of the dam's costs.

The Corps of Engineers has been involved in the evolution of Plan 6 because of the flood control element of the project. Because Cliff Dam is proposed to serve flood control purposes, the Corps, as well as the SRP, will have ongoing responsibilities for the management of the Salt-Verde reservoir system. In addition, the Corps was the primary agency involved in groundwater recharge research carried out in the 1970s in Arizona. As augmentation programs are developed by the AMAs, the Corps may also play a greater role in this regard.

IV. Hydrologic Model

The central objective of this study is to identify the most likely uses of increased streamflow that could hypothetically be made available. Because the emphasis is on a realistic assessment of potential allocations, existing water distribution laws, institutions, and practices were taken as given. In particular, the reservoir operation rules employed by the SRP were directly incorporated into the analysis.

A. Objective of the Model

Streamflow entering the Verde reservoir system is credited to three different accounts: Salt River Project (SRP), Phoenix, and Indian reservations. The method used by SRP to determine which account to credit depends upon the water level in the reservoir system. Each account gets credit for the water that fills its part of the reservoir. Therefore, in order to determine who will get the credit for a given monthly stream inflow, it is necessary to know the water level in the reservoir system at the beginning of the month. Furthermore, the Verde reservoir system is operated in conjunction with the Salt River reservoir system, and therefore can not be looked at as a separate and independent system. Thus, the purpose of the hydrologic model is to simulate the conjunctive operation of the Salt and Verde Rivers reservoir system and account for the allocation of the inflow.

A model used by the SRP was adapted for this purpose. A drawback of the SRP model for this study is that it only uses historical monthly flows as inputs. Because a synthetic streamflow trace would give a wider range of expected values and allow more realistic considerations of extremes for predictive purposes, a model to calculate these values was developed and interfaced with the SRP model. Another component of the hydrologic model

calculates the amount of additional flow obtained from vegetative modification based on the return period of the flow in the Verde River.

The final component takes into account the changes involved with the addition of Cliff Dam on the Verde River and the modification of Roosevelt Dam on the Salt River.

Each of these components of the hydrologic model used in this study are discussed in the following sections, beginning with the streamflow, then the additional flow, then SRP's model, and finally the Plan 6 model.

B. Model Components

Streamflow Model

Based on analysis of 93 years of monthly streamflow data (1889-1981) from the Verde River above the present location of Horseshoe Reservoir and the Salt River and Tonto Creek above Roosevelt Reservoir, it was decided to model the system using two first-order Markov models. One model was used for the Verde River flow and the other to model for the combined flow of the Salt River and Tonto Creek.

Markov models have been used in streamflow synthesis since the early 1960's (Fiering, 1967). The basic assumptions of these type models are that the flow in any given month is normally distributed about the mean flow for that month, and may or may not be independent of the previous monthly flows. In most areas, monthly streamflows are not normally distributed, but by using a logarithmic transformation of the data an acceptable fit to a normal distribution can be obtained.

In this study, the data were examined with and without the log transformation. It was decided to use the log transformed data because it more closely fit a normal distribution than did the raw data. Also, the variances of the raw or untransformed data were larger than the means in a

number of the months (Tables IV.1 and IV.2), which tends to result in generation of negative flows when using Markov models.

The next step was to determine the correlation of one month flows to the preceeding monthly flow of both rivers. As can be seen in Tables IV.1 and IV.2, during the spring runoff months there is a fairly high correlation while in the remainder of the year it is low. In any case, it was assumed that the correlation was sufficiently significant to indicate the level of dependence between monthly flows as used in the Markov model.

With this information the two first order Markov models were constructed using the following formula:

$$Q_m = \bar{Q}_m + r_{m/m-1} \frac{s_m}{s_{m-1}} *(Q_{m-1} - \bar{Q}_{m-1}) + t * s_m * (1 - r^2_{m/m-1})^{\frac{1}{2}} \qquad (4.1)$$

where:

Q_m = flow of month m

$\bar{Q}_m$ = average flow of month m

Q_{m-1} = flow of month (m-1)

$\bar{Q}_{m-1}$ = average flow of month (m-1)

$r_{m/m-1}$ = correlation between flows of month m and month (m-1)

s_m = standard deviation of month m

s_{m-1} = standard deviation of month (m-1)

t = normal random variate

The models were run for 1000 years and the mean and standard deviation of the simulated data were compared with the historical data. The difference in any one month was less than 2 percent, which indicated that the models would be sufficiently representative to use in the simulation study.

In order to appropriately use the Salt River and the Verde River Markov models together, the actual monthly flows in the two rivers must be

Table IV.1. Statistics of Salt River Streamflow

	(a) Flows in acre-feet				(b) Natural log transformation of flows			
Month	Mean	Standard Deviation	Correlation to Previous Month	Skew	Mean	Standard Deviation	Correlation to Previous Month	Skew
October	26,167	40,305	0.089	6.27	9.82	.691	0.089	1.44
November	28,009	39,423	.294	4.72	9.89	.694	.294	1.67
December	56,469	93,566	.464	2.97	10.23	1.018	.463	1.34
January	75,749	136,430	.304	5.18	10.51	1.094	.306	.86
February	104,249	162,973	.270	3.50	10.82	1.161	.278	.52
March	143,499	159,799	.399	2.66	11.39	1.013	.403	-.07
April	128,100	117,765	.736	1.99	11.35	.965	.737	-.24
May	61,968	65,877	.849	2.78	10.66	.847	.849	.26
June	21,981	17,869	.920	1.96	9.75	.688	.921	.36
July	21,956	23,466	.303	6.13	9.77	.612	.302	.57
August	41,649	34,430	.326	2.61	10.40	.659	.325	.43
September	30,461	25,088	.386	2.14	10.07	.684	.388	.38
	740,257							

Table IV.2. Statistics of Verde River Streamflow

	(a) Flows in acre-feet				(b) Natural log transformation of flows			
Month	Mean	Standard Deviation	Correlation to Previous Month	Skew	Mean	Standard Deviation	Correlation to Previous Month	Skew
October	18,970	27,436	0.065	7.25	9.59	0.566	0.066	2.10
November	22,790	28,667	.336	4.09	9.76	.584	.336	2.39
December	43,111	59,231	.468	2.42	10.16	.869	.468	1.46
January	51,225	67,527	.262	3.39	10.34	.912	.263	.94
February	87,169	141,322	.312	3.41	10.64	1.125	.315	.74
March	102,115	108,528	.351	2.26	11.02	1.060	.358	-.04
April	57,177	72,197	.386	2.51	10.40	1.025	.387	.38
May	16,593	24,026	.472	4.71	9.39	.641	.472	1.97
June	7,395	3,119	.314	1.97	8.83	.385	.313	-.05
July	12,333	13,116	.050	6.09	9.22	.554	.051	1.12
August	24,833	19,563	.331	2.28	9.90	.637	.330	.40
September	20,822	20,545	.155	2.65	9.67	.663	.156	1.08
	464,533							

sufficiently well correlated. The actual correlations of the monthly flows, based on 93 years of data, range from 0.49 in May to .97 in February, and average 0.78 (Table IV.3). In the high runoff months (Jan.-April) the average correlation is 0.87. These correlation coefficients were assumed to be sufficient to support the use of the same random number in both models for the same month, or, in other words, to assume that the flow in the two rivers are 100 percent correlated.

In summary, the final flow models used were first-order Markov models for the Verde and Salt Rivers assuming a 100 percent correlation between flow in the two rivers in any given month. These simulated flows, then, would be the pre-increase (from vegetative modification) inflows into the reservoir system.

Increased Flow Model

In conjunction with the Markov model which produced the synthetic pre-increase streamflow, it was also necessary to predict the increased flow resulting from vegetative modification for the same period. Briefly, the annual runoff increase from the national forests was calculated for a given recurrence interval by multiplying potentially treatable acreage of given vegetation types by per acre runoff increases, where runoff increase per acre was calculated based on precipitation and other inputs, and where precipitation was associated with a corresponding runoff recurrence interval by a precipitaton-runoff relationship. The annual runoff increase was then allocated on a monthly basis. The separate steps of the procedure are as follows:

1. The number of acres of chaparral and ponderosa pine vegetation on the Prescott, Kaibab, and Coconino National Forests in the Verde River watershed that could conceivably be modified was estimated.

Table IV.3. Correlations between Verde River and Salt River Monthly Flows

Month	% of Annual Flow Verde River	 Salt River	Correlation
October	4.1	3.5	0.886
November	4.9	3.8	.889
December	9.3	7.6	.892
January	11.0	10.2	.873
February	18.7	14.1	.972
March	22.0	19.4	.916
April	12.3	17.3	.742
May	3.6	8.4	.486
June	1.6	3.0	.535
July	2.7	3.0	.849
August	5.3	5.6	.759
September	4.5	4.1	.539

Average Correlation = 0.78

Based on Senn's (1976) inventory, 457,000 acres of ponderosa pine were assumed available for thinning to an overstory stocking of 30 ft^2 of basal area. Similarly, from T. Brown et al. (1974) 60 percent of 51,126 acres of chaparral were assumed available for conversion to grass.

2. Runoff increases per acre were estimated using the Baker-Kovner equation for pine (from H. Brown et al., 1974) and a modification of Hibbert's equation (Hibbert et al., 1974) for chaparral (T. Brown et al., 1974). Both equations use precipitation as the major independent variable. The pine equation requires additional inputs (e.g., basal area) which were taken from Senn (1976).

3. Precipitation-runoff equations were estimated from data for areas similar to those which could be treated to increase runoff to the Verde River. The ponderosa pine equation, based on from 16 to 25 years of data, including both untreated and treated conditions, at 12 Beaver Creek watersheds (a total of 257 entries), was as follows:

$$RO = .94\ P - 18.49 \tag{4.2}$$

where:

RO = annual runoff in inches

P = annual precipitation in inches

The chaparral equation, based on from 22 to 35 years of pre-treatment data at 4 chaparral experimental watersheds (a total of 102 entries) was as follows:

$$RO = .46\ P - 8.80 \tag{4.3}$$

Coefficients of determination for the pine and chaparral equations were 0.71 and 0.67, respectively.

4. Values for annual streamflow in the Verde River and tributaries were fit to a distribution (log-normal) to obtain return periods (or exceedence probabilities) for given annual streamflows as a proportion of mean annual streamflow. The data for this analysis are based on U.S. Geological Survey records at the following streamflow gaging stations: Verde River near Clarkdale, Oak Creek near Cornville, Wet Beaver Creek near Rimrock, Dry Beaver Creek near Rimrock, West Clear Creek near Camp Verde and Verde River near Tangle Creek.

5. The precipitation-runoff equations developed in step 3 (equations 4.2 and 4.3) were combined with the return period-streamflow relationships of step 4 to give a frequency distribution for mean area precipitation for those watersheds where precipitation records were not available.

6. Using the above distribution (step 5) with the runoff increase equations calculated in step 2, a frequency distribution for increased flows was obtained. The results of this analysis are shown in Table IV.4, which presents the maximum runoff increase to be expected for a selected return period. Regression analyses, similar to that conducted in step 4, gave the following:

$$\Delta Q(P) = Ln(T_r) * 19.946 * 1000 \quad (4.4)$$

and $$\Delta Q(C) = Ln(T_r) * 11.683 * 1000 \quad (4.5)$$

where:

$\Delta Q(P)$ = annual added flow from ponderosa pine areas (acre-feet)

$\Delta Q(C)$ = annual added flow from chaparral areas (acre-feet)

The above equations have coefficients of determination of 0.91 and 0.92, respectively.

7. The runoff increases shown in Table IV.4 (or calculated from equations 4.5 and 4.6) are for the maximum level (i.e., all potentially treatable acreage--see step 1) under consideration. The other two treatment levels for which calculations were made are 50 and 10 percent of those maximums.

8. Studies by Hibbert et al. (1974) for chaparral and H. Brown et al. (1974) and Ffolliott and Baker (1977) for ponderosa pine indicate that practically all of the increases come in the December-to-April period. Based on those studies, the annual runoff increases of Table IV.4, or the 50 and 10 percent subsets of those increases, were assumed to occur as follows:

	Ponderosa Pine	Chaparral
December	16.5	20
January	10.2	20
February	14.2	20
March	33.0	20
April	26.1	20

9. Information from the Verde River near Tangle Creek station was used to arrive at a frequency distribution for the annual pre-increase streamflow of the Verde River. Using a logarithmic transformation, a linear regression analysis resulted in the equation:

$$Ln(T_r) = -0.379 + 0.031 * Q/10,000 \qquad (4.6)$$

Table IV.4. Predicted Streamflow Increase and Associated Pre-increase Flow on the Verde River Watershed.

Return period (year)	Probability of exceedance, (%)	Streamflow Increase (1000 acre-feet) Ponderosa Pine	Chaparral	Total	Pre-increase flow (1000 af)
1.01	99	15.2	8.1	23.3	125.5
1.05	95	16.1	8.6	24.7	138.0
1.11	89	16.5	9.3	25.8	155.0
1.25	80	22.7	10.1	32.8	194.3
2.0	50	26.8	15.1	41.9	345.9
5.0	20	42.1	25.2	67.3	641.5
10.0	10	54.7	32.7	87.4	865.1
20.0	5	63.1	37.7	100.8	1,088.7
100.0	1	78.6	45.3	123.9	1,607.9

where:

T_r = return period in years

Q = annual flow in the Verde River (acre-feet) and the coefficients of determination is .98

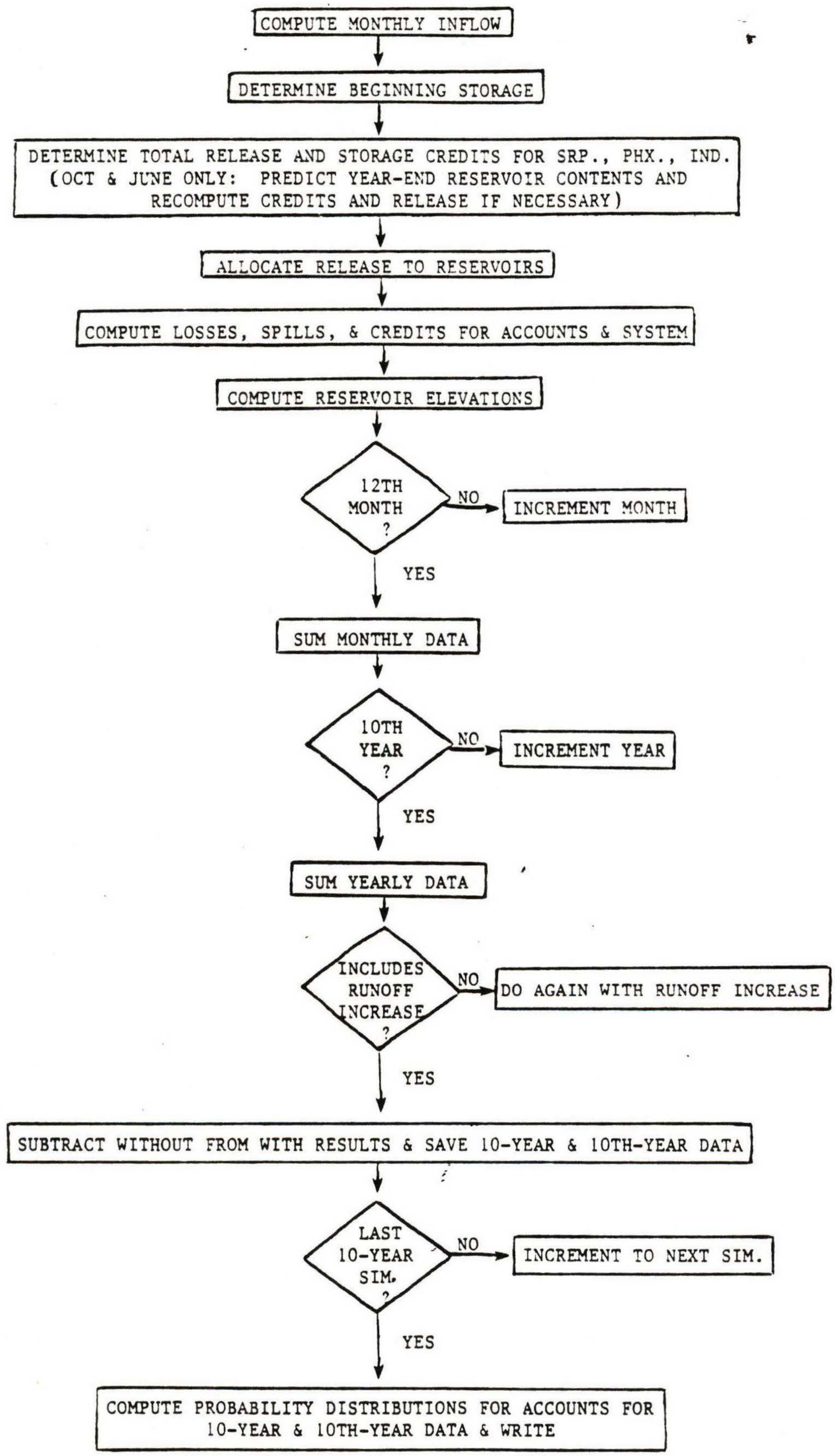
These normal (pre-increase) flows were associated with the runoff increases via the assumption that the return periods of operations 4.4, 4.5 and 4.6 were comparable. See table IV.4 for the associated pre-increase flows.

Reservoir Operation Model

The reservoir operation model simulates (1) operation of the system of reservoirs on the Salt and Verde Rivers and (2) allocation of the inflow to various use and loss categories. The model output lists possible allocations of the inflows with and without runoff increases, as well as the change in allocation attributed to the runoff increases, along with associated probabilities of occurrence. The expected values of the probability distributions are also listed. The reservoir operation and inflow allocation portions of the model were initially developed by Randy Chandler of the U.S. Bureau of Reclamation (USBR) in 1979, and modified by the USBR as described in the SRPSIM User's Manual (Clemm, 1983). Further modifications were made for this study to replace historical flows with simulated flows, predict increased flows, and output probability density functions of the results. Major aspects of the model are presented in a flow chart in Figure 3.

Operation of the model begins with inflows to Roosevelt and Horseshoe Lakes and ends with releases to Granite Reef Dam. Reservoir operations are simulated on a monthly basis. Program input includes annual water demands, reservoir and groundwater pumping information, and monthly inflow data. The annual water demand is distributed on a monthly basis for each water

Figure 3.--Flow Chart of Simulation Model



user and varies with the amount of water in storage. Credits for water are issued to each water-user account depending on the level of water in the reservoir system in the Verde River. Inflow and credits are calculated separately with and without runoff increases. The with minus the without case determines the effect on water use of the runoff increases. Output includes annual reservoir releases, losses, and spills, power used for groundwater pumping, and system accounting for the City of Phoenix, the Salt River Indians and the Salt River Project.

The program starts by reading input data such as the demand for each account (Table IV.5), the evaporation constants for each reservoir (Table IV.6), the maximum conservation storage capacities for each reservoir (Table IV.7), and the restrictions on groundwater pumping. The volume of groundwater to be pumped is calculated by two approaches (Clemm, 1983). The first approach is based on monthly historical pumping for respective system storage contents, and the other is based on monthly demand and pumping capacity. The lesser of the two calculations is used.

The water year (October to September) data file for Roosevelt and Horseshoe inflows starts in 1889 and continues through the 1982 water year. Because simulated flows are used, the initial reservoir storage for each 10-year period must be the same, to allow for a statistically sound analysis. For this purpose, it is assumed that at the beginning of each 10-year period the reservoirs contained the water quantities listed in Table IV.7, which were developed by the SRP for simulation purposes.

The program then reads normal random deviates and computes the monthly flows for the Salt and Verde Rivers. Then, storage credits for the City of Phoenix and the Salt River Indians are determined, which is a function of BOM storage in the Verde River system. The City of Phoenix receives credit when the BOM of the Verde is between 236,581 and 309,613 acre-feet. In

Table IV.5. Monthly Distribution of Annual Water Demand.

Month	Distribution Factor, % SRP	Phoenix	Indians
Oct	6	10	4
Nov	3	0	3.5
Dec	4	0	3
Jan	3	0	3
Feb	5	0	4
Mar	9	0	8
Apr	10	0	11
May	11	0	10
Jun	13	15	11
Jul	14	30	14
Aug	12	25	15.5
Sept	10	20	13
Annual Demand, 1000 ac-ft	1145	25	32.5

Table IV.6 Evaporation Losses for Salt and Verde River Reservoirs

Month	Evaporation, ft/mo	
	Salt River	Verde River
Oct	0.27	0.43
Nov	.11	.24
Dec	.0	.13
Jan	.0	.08
Feb	.07	.14
Mar	.19	.27
Apr	.46	.49
May	.67	.72
Jun	.83	.85
Jul	.75	.75
Aug	.56	.61
Sept	.46	.58
Annual total	4.37	5.29

Table IV.7. Maximum Conservation Storage Capacities and Beginning Simulations Storage of the Salt and Verde River Reservoirs.

Reservoir	Capacity	Beginning Storage
	(1000 acre-feet)	
Roosevelt	1336.70	979.3
Lower Salt*	372.80	354.2
Horseshoe	131.43	113.4
Bartlett	178.19	160.4

*Includes Saguaro, Canyon and Apache

this range, the City receives all of the positive change in storage up to a maximum cumulative gatewater credit of 150,000 acre-feet. The Indians receive credit when the BOM in the Verde is between 8,909 and 178,186 acre-feet. Within these values, the Salt River Indians receive 20 percent of the positive change in storage up to a maximum cumulative storage credit of 60,000 acre-feet.

In October and June, a prediction is made of the year-end contents of both reservoir systems to determine if a change in SRP's allocations is necessary. If the predicted year-end contents in October are less than 500,000 acre-feet, SRP reduces reservoir releases for its members by 20 percent. In June, if the year-end contents are estimated to be more than 1,600,000 acre-feet, then SRP's demand is increased by 15 percent.

The next step determines the reservoir from which water is to be released and calculates any spill. Normally, from October to April all of the required water is released from the Verde River system and none from the Salt. From May to September, the usual policy is to release 50 cubic feet per second from the Verde and the rest of the demand from the Salt system. These criteria change when there is an extreme imbalance of water stored in the two reservoir systems or a spill occurrs from only one river system. An extreme imbalance is considered to be the case during the period October to April if the Verde system predicted EOM storage is very low and the corresponding Salt system predicted EOM storage is fairly high. During the period May to September, an imbalance is the situation when the Verde storage is fairly high and the Salt storage is less than approximately 90 ± 5 percent of capacity. In this case, a large portion of the water is released from the Verde system.

A spill occurs when the inflow minus release results in the total water for that system to be greater than the conservation storage capacity of the system. When there is a spill on the Verde River, the amount is deducted from SRP's account. When the Salt spills, the Phoenix gatewater account is changed if that account is greater than 73,032 acre-feet. Otherwise, the SRP account is charged. Evaporation and seepage losses are deducted at this time, based on the amount of water in storage and the month.

Next, all water accounts are updated. This involves computing the amount of Phoenix gatewater spilled from the Salt River, and deducting the amount of water used by each account from their respective cumulative totals.

The amount of power required to pump the groundwater is calculated based on the amount of groundwater pumped and the efficiency of the pumping plant. The plant efficiency is obtained from a curve fitted to data on the energy used to pump various amounts of water.

At the end of each year, monthly values are summed for the following accounts: Granite Reef spills, Phoenix gatewater credits, Phoenix losses, Phoenix gatewater spills, Indian credits, SRP credits, SRP losses, added flow resulting from vegetative modification, and energy to pump groundwater. These annual totals are cumulated for 10-year periods, and along with each of the 10th-year values, are stored for the (1) pre-increase case, (2) post-increase and (3) difference between the two. Distributions were then developed for each account for each of the three situations.

Plan 6 Model

The reservoir operation model for the existing situation was modified to accomodate two additional scenarios. The first, called "Plan 6," incorporates the proposed Plan 6 of the Central Arizona Project, including building Cliff Dam and modifying Roosevelt Dam. The second, referred to as "Modified Plan 6," is identical to the first except that 50 percent of the flood control space in Cliff is used for conservation storage from April to November. Table IV.8 presents the space allocation for Roosevelt and Cliff reservoirs.

In the Plan 6 scenario, Cliff Dam replaces Horseshoe Dam on the Verde River. This increases the conservation storage on the Verde from 309,620 acre-feet to 494,620 acre-feet (from 67 percent to 106 percent of average annual flow entering the reservoirs). The additional storage space is labeled "Verde Plan 6" and that account is credited when there is a positive change in storage between 309,620 and 494,620 acre-feet. A maximum storage credit of 185,000 acre-feet is placed on this account. On the Salt River, the capacity in Roosevelt Dam is increased between April and November from 1,455,900 acre-feet to 1,912,300 acre-feet by using 80 percent of the flood control space as conservation storage space. This space is labeled "Salt Plan 6" and is credited only from April to November when there is a positive change in storage in the range specified. The water in the flood control space in both Cliff and Roosevelt Dams is not allowed to remain in storage but is spilled at a rate so that the flow of the Salt River in Phoenix does not exceed 92,000 cfs. Any water in the dam safety space is spilled at once. (This, of course, would actually happen on a day to day basis. Because the model works on a monthly time step, it assumes that all water will be spilled in a given month.)

Table IV.8. Space Allocation for Roosevelt and Cliff Reservoirs*

	Reservoir Capacity in (1000 acre-feet)		
Allocation	Roosevelt	Cliff	Modified Cliff
Conservation			
Dec-Mar	1,456	316	316
Apr-Nov	1,912	316	538
Flood Control			
Dec-Mar	565	445	445
Apr-Nov	108	445	222
Dam Safety			
Dec-Mar	774	861	861
Apr-Nov	774	861	861

*Projections of space allocation for Plan 6 have recently been revised (Salt River Project 1985). The revisions increase conservation storage by from 6 to 10 percent and change flood control storage by less than 2 percent. These changes should not seriously affect the results presented here. Note that the revisions also increase dam safety storage by from 10 to 28 percent.

It is not certain who would receive the credits accruing to the Verde Plan 6 and Salt Plan 6 accounts or how and when the credits would be used. Therefore, all credits are assumed to be used in the year they are accumulated. That is, there is not carry over of these credits between years.

Other than these changes, the program was run exactly as described in the previous section. Initial storage levels were not changed. For example, initial Cliff storage was 113,400 acre feet, as it was for Horseshoe (Table IV.7). Thus, at the beginning of each 10-year simulation, Cliff was 42 percent full while Horseshoe was 86 percent full.

In the Modified Plan 6 scenario, 50 percent of the flood storage space in Cliff Dam is used for conservation storage from April to November and is credited to the Verde Plan 6 account.

Operation of the Models

The program was run for the three situations (the current situation, with Plan 6, and with Modified Plan 6) at each of three treatment levels. The output from each run includes distributions for the pre-increase, for the post-increase, and for the difference between the two.

V. ALLOCATION OF STREAMFLOW INCREASES UNDER EXISTING INSTITUTIONAL ARRANGEMENTS

A. Introduction

This chapter reports the results of routing and allocating the increased streamflow based on the existing reservoir operation rules, and the court decrees, contracts, and agreements that control water allocation. To reiterate: three levels of increased flows are used. The 100 percent level assumes treatment of 457,000 acres of ponderosa pine and 30,675 acres of chaparral (60% of the total 51,126 acres) in the Coconino, Kaibab, and Prescott National Forests in the Verde River watershed. Treatment of the ponderosa pine would involve intensive thinning. The chaparral would be converted to grasses and forbs. At the 100 percent level of treatment, in a statistically average ten-year period, an additional 369,500 acre feet of water would be produced. The 100 percent treatment level represents a hypothetical upper bound on potential treatment effects. The other two levels of increased streamflow are 50 percent and 10 percent of the expected yield from maximum treatment, or 184,000 and 37,000 acre feet per average ten-year period, respectively.

Because of the storage facilities, water not used in one year can be carried over to the next. A multi-year (ten-year) simulation period was used in order to incorporate the effect of storage on water use. The results and analysis are based primarily on expected values for the ten-year period. The expected values are the probability-weighted average of the distribution of ten-year results, each constructed from 100 ten-year simulations.

Estimates are tabulated for the following categories:

(1) Total inflow credits assigned to the Phoenix gatewater account and the Salt River Project;

(2) Water losses due to seepage and evaporation assigned to the Phoenix gatewater account and the Salt River Project;

(3) Water spills at Granite Reef Dam. This category includes water which is physically lost from use in the Phoenix metropolitan area but may be used farther downstream, and "free" water which is offered to SRP members.

(4) Water spills on the Salt side which are debited to Phoenix's gatewater account;

(5) The net credit to Phoenix's gatewater account which is their inflow credits minus losses and gatewater spills;

(6) The net credit to SRP which is their inflow credits minus their losses;

(7) The credit to the Indians;

(8) The amount of energy which SRP would have used to pump groundwater had the additional flow not been added to the system.

Water is spilled on the Salt side of the system when the flow to the reservoirs exceeds their available storage capacity. The first increment spilled is debited to the Phoenix gatewater account, until the account drops to 75,000 acre feet. The water debited to Phoenix's gatewater account is credited to SRP, if SRP uses it to meet member demands, or is accounted as spill at Granite Reef if it is actually spilled there or if it is offered to Project members as "free" water. Thus, this increment of flow is accounted for in the category of gatewater spills and in the category of SRP credits or Granite Reef spills, and when summing absolute values or percentages, it is counted only once.

While the analysis relies on ten-year values, one-year values are also reported because they indicate annual extremes. The one-year values are based on the distribution of the tenth-year simulation results (i.e., the results for the tenth year of each of the 100 ten-year simulations were tabulated into a distribution). Values extracted from one-year distributions, for each category mentioned above, include (1) one-year

periods when no additional flow is allocated, (2) the extreme values and the percent of the time the extremes will occur, and (3) the interval of the distribution which contains the concentration (and the model of allocations). In addition, tables reporting the expected values of allocations for the one-year values are found in Appendix A.

B. Results

The expected value of the distribution of allocations of the additional streamflow in a 10-year period is shown in Table V.1. Table V.2 shows the percentage increase in net allocations caused by the runoff increase. These numbers are calculated by dividing the increase in allocation by the pre-increase allocation. Table V.3 describes the distribution of one-year results and Table A.1, Appendix, describes the expected values of one-year results.

Spills at Granite Reef Dam

In an average 10-year period, regardless of the extent to which vegetation modification is carried out, the greatest portion of the runoff increase, 62-63 percent, is spilled at Granite Reef Dam (Table V.1). (The percentage allocations are apparently insensitive to the degree of runoff increase within the range of increases postulated.) Some of this water recharges aquifers in the Valley and some flows downstream, being physically lost from use in the Phoenix metropolitan area. In addition some, termed "free water", may be released into the Project's canals for use free of charge by SRP members (this water is not actually "spilled"). There are no readily available data on how much "free" water is applied to crops, or how much spilled water recharges the aquifer in the Phoenix area. However, in most spill years, it can be expected that the pre-runoff increase spills would largely satisfy the demand to free water, such that

Table V.1. Allocation of Additional Flow Under Existing Institutional Arrangements.

Expected Value [1] Per Ten-Year Period with Treatment Levels of

Account	100% Flow, 1000 af	100% % of Total	50% Flow, 1000 af	50% % of Total	10% Flow, 100 af	10% % of Total
Salt River Project						
Inflow	115.8		56.5		12.0	
Losses	9.9	3	5.3	3	1.4	4
Net	105.9	29	51.2	28	10.6	29
Phoenix Gatewater						
Inflow	39.3		21.3		4.4	
Losses	4.6	1	2.5	1	0.5	1
Spills	17.4		8.2		1.8	
Net	17.3	5	10.6	6	2.1	6
Indians	--	--	0.1	--	0.1	--
Spills at Granite Reef Dam [3]	229.0	62	114.3	62	23.3	63
Total Additional Flow	369.5	100	184.8	100	37.0	100 [2]
Change in SRP Groundwater Pumping (Gigawatt-hrs)	31.6		16.5		3.1	

1) Probability-weighted average.
2) Does not add to exactly 100 due to rounding off and averaging.
3) There is no logical reason for the percent spilled to be greater at the 10% level of increase than at the 100% or 50% level of increase. The difference is noise attributed to the procedure for calculating expected values from interval midpoints.

Table V.2. Change in Streamflow and Allocation from Existing Situation with Vegetation Modification

Item/Account	Percent Increase[1)] for Treatment Level of 100%	50%	10%
Spills at Granite Reef Dam	10	5	1
SRP Net Credit	1	<1	<1
Phoenix Net Gatewater Credit	7	4	<1
Indian Credit	0	0	0
SRP Groundwater Pumping	2	1	<1
Streamflow in Verde	7.9	3.9	0.8

1) Average annual increase divided by average annual pre-increase amount.

Table V.3. Probabilities of Extreme Values of Additional Flow Under Existing Institutional Arrangements.

	% of Years When Allocation is 0	Extreme Values % of Years	Extreme Values Interval (1000 af)	Interval of Largest % % of Years	Interval of Largest % Interval (1000 af)
<u>Total Inflow Credits</u>					
Salt River Project					
100% of Increase	0	1	48-52	34	0-4.0
50% of Increase	0	1	38-40	32	0-2.0
10% of Increase	0	3	7.6-8	34	0-0.4
Phoenix Gatewater Account					
100% of Increase	16	17	18-20	56	0-2.0
50% of Increase	13	16	9-10	60	0-1.0
10% of Increase	12	15	1.8-2	65	0-0.2
<u>Losses and Spills</u>					
Spills at Granite Reef Dam					
100% of Increase	3	2	150-175	77	0-25
50% of Increase	3	2	75-87.5	77	0-12.5
10% of Increase	5	1	17.5-20	73	0-2.5
Salt River Project Losses					
100% of Increase	0	2	4-4.5	36	0-0.5
50% of Increase	0	1	2.8-3	46	0-0.3
10% of Increase	30	2	1.0	30	0
Phoenix Losses					
100% of Increase	22	1	4-5	51	0-1
50% of Increase	22	1	3-3.5	48	0-0.5
10% of Increase	25	1	0.7-0.8	45	0-0.1
Gatewater Spilled					
100% of Increase	0	1	37-40	92	-2-1.0
50% of Increase	0	1	18.5-20	92	-1-0.5
10% of Increase	0	2	3.7-4.0	97	0-0.1
<u>Total Additional Flow</u>					
100% of Increase	0	2	140-150		
50% of Increase	0	2	70-75		
10% of Increase	0	2	14-15		
<u>Change in SRP Ground Water Pumping</u> (Gigawatt-hours)					
100% of Increase	0	2	19-20	33	0-1
50% of Increase	0	2	9.5-10	41	0-0.5
10% of Increase	0	8	1.9-2.0	84	0-0.1

the runoff increase that contributes to the spill category would in fact be spilled at Granite Reef.

The water spilled at Granite Reef Dam comes from both the Salt and Verde Rivers. Water from the Verde is spilled when the inflow exceeds the available storage capacity of Bartlett and Horseshoe Reservoirs. Based on data for 1889 through 1979, the annual average spill from the Verde system assuming current storage and operating procedures, is 203,590 acre feet per year, or approximately 43 percent of the average yearly streamflow of the Verde River at the confluence with the Salt (Salt River Project, 1979). Spills from the Verde River have accounted for 51 percent of the average yearly system-wide spills at Granite Reef Dam.

In a ten-year period, the expected increases in spill at Granite Reef Dam associated with the 100, 50, and 10 percent levels of increased flow are 229,000, 114,300, and 23,300 acre feet, respectively (Table V.1). These spill increases amount to 10, 5, and one percent of the pre-increase spills, respectively (Table V.2).

On an annual basis, there is a 3-5 percent chance that none of the runoff increase will spill, and about an 80 percent chance that spills of the increase will be below 25,000 acre feet. At the 100 percent level of increase, there is a 2 percent chance that 150,000 to 175,000 acre feet of runoff increase will spill (Table V.3).

Spills which result in flood damage, of course, raise concerns about liability. Although the SRP maintains that it does not have any legal responsibility or authority for flood control, SRP has been sued in the past for damages resulting from water spilled during storm events. To the extent that vegetative modification on national forests could be linked to

spill events, the Forest Service and any cooperating agency could be a party to suit brought as a result of downstream damages.

Salt River Project

The net (after evaporation and seepage losses are subtracted) additional flow assigned to SRP is approximately 29 percent of the total additional streamflow at each level of increase. The expected values of these net inflow credits amount to 105,900, 51,200, and 10,600 acre feet in a ten-year period for the 100, 50, and 10 percent levels of increased flow, respectively (Table V.1). These credits represent no more than one percent of the net pre-increase surface water allocations to SRP (Table V.2). In any one year, at the 100 percent level of increase, there is a 1 percent chance that the increase to the total inflow credit would exceed 48,000 acre feet, and a 34 percent chance that it would not exceed 4000 acre feet (Table V.3).

Agriculture currently receives about 62 percent of the total water delivered by SRP, municipal and industrial users receive 26 percent, and 12 percent is used for urban irrigation (parks, playgrounds, homes, schools, and churches) (Salt River Project, 1982). Pumped water supplements the less expensive surface water in all years. Pumped water is mixed with surface water and allocated by land area. Additional flow would probably be allocated proportional to existing (pre-increase) flow.

Since pumped water annually supplements surface water, the additional water would in effect be used to offset groundwater pumping, leaving the total water use unchanged. Agricultural lands, for example, require 5 to 6 acre-feet per year. The surface allotment supplied by the SRP has averaged somewhat more than the basic assessment of 2 acre-feet per year (Salt River Project, 1982). The difference is made up by water pumped by the SRP or

pumped by farmers from their own wells, and by spill water and additional stored water in wet years. Considerable savings would thus be realized if groundwater pumping were reduced.

By the year 2000, agriculture's share of total water supply is predicted to decline to 14 percent, while municipal and industrial demands are expected to increase to 72 percent and urban irrigation uses are expected to increase only slightly to 14 percent (Salt River Project, 1982). As Project land is converted from agricultural to municipal uses, there will be a short-term reduction in combined water needs for agriculture, municipal, or industrial purposes. However, as urbanization continues, water needs within the Project are projected to equal or exceed current demands. For example, pumpage requirements are estimated to drop to 85,000 acre feet a year by the year 2000, but to climb to 200.000 by the year 2034. These estimates assume an increase in density from 7.5 people per acre in 1982 to 11 people per acre by 2034, and a drop in per capita use to 160 gallons per day (Salt River Project, 1982). Thus, although pumping is expected to decline somewhat in the short run, it is not expected to drop sufficiently to affect the potential for runoff increases of the magnitude considered herein to reduce pumping costs.

The net effect of the increase in SRP credit, under existing institutional and legal arrangements, would be to reduce pumping. Only if the credit increase could be used in an area where water demand is high and supply from groundwater pumping is not an option would this not be the case. Although the lack of groundwater for development may be the case in some areas of the Phoenix metropolitan area, use of SRP water off project is not forseen. For example, because of the projected levels of urban population and groundwater needs on Project lands, neither the SRP nor the

City of Phoenix is likely to favor allowing any additional water accruing to the SRP to be used off-Project (Chase 1983b, Juetton and Mason 1983).

Phoenix Gatewater Account

The net (of evaporation and seepage losses, and reductions caused by Salt River spills) inflow credit to the Phoenix gatewater account, at all levels of increase in streamflow, is 5-6 percent of the total additional flow. These net inflow credits average 17,300, 10,600, and 2,100 acre feet per ten-year period for the 100, 50, and 10 percent levels of increase, respectively (Table V-1). These net credits are about 7, 4, and 1 percent of the pre-increase credits, respectively (Table V-2).

On an annual basis there is a 12-16 percent chance that none of the runoff increase will accrue to the Phoenix inflow credit. At the extreme, there is a 17 percent chance that Phoenix will receive a total credit of 18,000-20,000 acre feet (Table V.3). The increase in net credits to Phoenix would average 210 acre feet per year with the 10 percent level of runoff increase (Table V.1). Even at the 100 percent level of increase, the increase in net credit to Phoenix's account is only about 1,730 acre feet per year (Table V.1), or about 7 percent of the 1980 Phoenix total water use of 240,000 acre feet.

Water availability does not currently limit growth in Phoenix. Ground water supplements surface water to meet demand. Thus, in the short-term, Phoenix would in effect use additional gatewater credits to offset groundwater pumping off-Project. Additional gatewater credits would also enable the City to more effectively husband its gatewater account.

For long-term water planning purposes, City staff has prepared three scenarios for meeting demands of off-project and non-member lands for the next fifty years. Each scenario assumes use of gatewater at 12,000 acre-

feet per year rather than the City's historical use rate, which has gone as high as 30,000 acre feet in a given year. The 12,000 acre feet figure is considered to be the long-term average supply of gatewater (Chase 1983a).

(1) Alternative 1 adds the City's proposed CAP allocation to the 12,000 feet of gatewater water. It also assumes 40,000 acre-feet of effluent would renovated and exchanged with agriculture for reuse. The balance of the City's water needs would be met with groundwater.

(2) Alternative 2 assumes receipt of additional CAP water and the renovation and exchange of 40,000 acre-feet of effluent. The balance of the City's supplies would be made up of groundwater until 2025 when other supplies would replace the City's reliance on groundwater.

(3) Alternative 3 calls for maximum use of CAP by receiving larger allocations and by purchasing additional amounts. This scenario would eliminate the City's dependence on groundwater in normal flow years, and delay utilizing reclaimed effluent until after the year 2000. Other supplies, however, would still be needed to make up ultimate demands.

As noted in Chapter III, approximately 74 percent of Phoenix's water is used for residential purposes. However, 48 percent of Phoenix's water is used for outdoor landscape irrigation. Conservation under the AMA plan will no doubt reduce the large amounts of water used for consumptive outdoor uses. This "saved" water would also allow growth to continue while reducing groundwater pumping levels.

The scenarios show demand being met by existing gatewater, groundwater, and others sources (e.g., CAP and effluent) until 2025 when, as a result of compliance with the Groundwater Management Act, still other sources (e.g., surface and groundwater transferred from other areas of the state or nation) would replace groundwater. The increases in Phoenix gate water resulting from vegetation modification, if they were available, would in effect replace the most expensive of such sources as long as demand was being met. If the point were reached where demand exceeded available supplies, the gatewater increases would allow increased water use. However, the degree to which water from vegetative modification would be

viewed by the Department of Water Resources or the City of Phoenix as a dependable, assured supply would no doubt affect the role that such increased flow could play in actually increasing water use.

Indian Communities

The Indians' right to normal flow water in the Verde system is the prior right and therefore the first to be satisfied. The Indians' right to developed water is also the first to be satisfied in the Verde system and it is a limited right. Only very rarely--in dry periods--would the Indians receive a portion of the additional water, and then it is a small amount. With the maximum level of additional flow, the Indians receive none of the additional water; the additional flow helps maintain reservoir storage above the level at which inflow accrues to the tribe. At the 10 and 50 percent treatment levels they receive about 100 acre-feet per ten year period. This is because in years of lower flow, reservoir storage falls to the point where some of the water is needed to satisfy the Indians' claim. The average expected value for the Indians' allocation is small with no adjustments to their current water rights. However, adjudication of Indian water rights could alter this situation.

Other Allocations

Other water users who might benefit from an increase in Verde River flow produced by vegetation modification are the Roosevelt Water Conservation District and the Buckeye Irrigation District. The amount of additional water these districts would receive would be quite small since their allocation is based on a percent of the amount of water diverted at Granite Reef Dam: 1.1 percent for Buckeye and 5.6 percent for Roosevelt of diversions for Association use. For example, if the SRP were to receive a total inflow credit of 12,000 acre feet per 10-year period at the 10

percent level of increase, the Roosevelt Conservation District would be entitled to approximately 629.8 acre feet over a 10-year period. The Buckeye Irrigation District's allotment would be 123.7 acre-feet every ten years.

Overview

Of the total additional streamflow available at all levels of increase over a ten-year period, approximately 62-63 percent of the water would be spilled at Granite Reef. If downstream damages occur, the USDA Forest Service and any cooperating entity might be sued. The SRP would receive 29 percent of the increases and the City of Phoenix gatewater account would be credited with 5-6 percent. The Indians would essentially receive no additional amounts.

Water allotted to SRP and Phoenix would most likely be used to reduce groundwater pumping. In this case, the value of the runoff increases would be equal to the cost savings from pumping less (composed of energy costs, well maintenance costs, and the costs associated with a dropping groundwater table). In the long run, the increases might also replace more expensive sources of water, as water users move toward meeting the safe-yield goal mandated by the 1980 Groundwater Management Act.

Generally, water has not been a constraint to growth in Arizona or in the Salt River Valley, and it is not likely to be a constraint within the next 20 years. While water rates are likely to increase as CAP water comes on line, one study cites the current director of the Department of Water Resources as stating that the state can continue to grow as long as it avoids big water-using industries (Brown, 1983). Any new source of surface water increases the flexibility of the user to mix and match supplies with demands.

VI. ALLOCATION OF STREAMFLOW INCREASES WITH PLAN 6

A. Introduction

Two scenarios involving the elements of Plan 6 that affect the Salt and Verde Rivers were modeled both with and without vegetative modification programs. This chapter reports the results of routing and allocating the three levels of increased streamflow for these two scenarios.

Cliff Dam on the Verde River will provide both flood control and new conservation storage. The additional conservation storage provided by Cliff Dam will accommodate up to 185,000 acre feet. Under the first scenario, the portion of the additional flow from vegetation modification that is made available for use by this additional storage space is assigned to "Plan 6, Verde." Also under the first scenario, on the Salt River, one half of the usable sediment pool space in Roosevelt Reservoir is used, each year and all year, by the Salt River Project (SRP) for conservation storage. In addition, 80 percent of the flood control space in Roosevelt--456,400 acre feet--can be used from April through November for water storage. This water is credited to "Plan 6, Salt."

The second scenario, referred to as Modified Plan 6 for discussion purposes, assumes the same conditions on the Salt River as does the first scenario. On the Verde River, however, 50 percent of the flood control space in Cliff--222,000 acre feet of volume--is available for water storage from April through November. This additional water is credited to "Plan 6, Verde."

This chapter thus summarizes the results of allocating additional flow from vegetation modification under Plan 6 and Modified Plan 6. As a basis for comparison, increases (over the current situation) in water allocation attributable to Plan 6 and Modified Plan 6 are first presented assuming no

vegetation modification. As in the previous chapter, the discussion focuses on ten-year values, although one-year values are presented in accompanying tables and in the Appendix (Tables A.2 and A.3).

B. Plan 6 and Modified Plan 6 with No Vegetative Modification

In a ten-year period, without vegetative modification upstream, a total expected value of 1,219,000 acre feet of normal flow could be made available for use by Plan 6: 647,000 acre feet on the Salt side of the system, and 572,000 acre feet on the Verde side. With Modified Plan 6, this credit could increase to an expected value of 1,319,000 million acre feet in a ten-year period (Table VI.1).

With the additional storage space of Plan 6, spills at Granite Reef Dam would be reduced by 1,233,000 acre feet (a 55 percent reduction). With Modified Plan 6 (utilizing in addition 50 percent of the flood storage in Cliff Dam) spills would be reduced by 1,540,000 acre feet in ten years (64 percent) (Table VI.1). Note, however, that initial (to begin each simulation) reservoir storage was lower for some Plan 6 reservoirs than for the existing situation scenario (e.g., conservation storage in Cliff was assumed to be 42 percent full compared with 86 percent for Horseshoe). Higher initial storage would tend to increase spills.

The net credit to the Salt River Project would decline by 5 percent under Plan 6, and 4 percent under Modified Plan 6. SRP credits decline because, with the increased storage available (and corresponding decrease in spilled water), the SRP portion of the dam is full more often (this of course assumes that SRP demands do not change as a result of the increased storage). The Phoenix gatewater account would receive less total credit but more net credit because of the reduction in spills. With Plan

Table VI.1. Change in Availability of Water in the Salt-Verde System with Plan 6 and No Vegetation Modification.[1)]

	Plan 6		Modified Plan 6	
	1000 af[2)]	%	1000 af	%
<u>Total Inflow Credits</u>				
Plan 6, Salt	647.0	-	673.0	-
Plan 6, Verde	572.0	-	646.0	-
Total Salt River Project Credits	- 405.0	- 5	- 305.0	- 3
Total Phoenix Gatewater Credits	- 62.5	-15	- 57.0	-14
<u>Spills and Losses</u>				
Spills at Granite Reef Dam	-1233.0	-55	-1540.0	-64
Salt River Project Losses	22.0	2	35.0	3
Phoenix Losses	7.0	16	9.1	21
Gatewater Spilled	- 79.0	-61	-80.0	-62
<u>Net Credits</u>				
Salt River Storage	647.0	-	673.0	-
Verde River Storage	572.0	-	646.0	-
Salt River Project	-430.0	-5	-340.0	- 4
Phoenix Gatewater	9.5	4	13.9	6
Indians	0.6	<1	- 4.4	- 1
<u>SRP Ground Water Pumping</u> (GWH)	42.0	3	78.0	6

1) Change from existing institutional arrangements.
2) Probability-weighted average per 10-year period.

6, the increase in net credit to the gatewater account is 9,500 acre feet (a 4 percent increase). With Modified Plan 6, the increase is 13,900 acre feet (6 percent) above pre-Plan 6 net credits. The total net additional water credits with Plan 6 are 799,000 acre feet per ten-year period. With Modified Plan 6 they are 988,500 acre feet per ten-year period (Table VI.1).

C. Plan 6 and Modified Plan 6 with Vegetative Modification

Table VI.2 shows the allocation of the additional (from vegetation modification) Plan 6 streamflow in a ten-year period. The percentage increase in net allocations caused by vegetation modification is shown in Table VI.3. Allocations under Modified Plan 6 are shown in Tables VI.4 and VI.5. One-year values for Plan 6 are shown in Table VI.6, while one-year values for Modified Plan 6 are shown in Table VI.7. Additional one-year values are found in tables A.2 and A.3 of Appendix A.

Spills at Granite Reef

The additional storage made available by Plan 6 and Modified Plan 6 reduces the anticipated spills at Granite Reef Dam associated with the runoff increases by almost 50 percent. With Plan 6, in a ten-year period, the expected spill increase ranges from 32 percent (at the 10 percent runoff increase level) to 38 percent (at the 100 percent level) of total runoff increases (Table VI.2), as opposed to about 62 percent without Plan 6 (Table V.1). Under Modified Plan 6, spills account for from 32 percent (at the 10 percent level) to 34 percent (at the 100 percent level) of total runoff increases (Table VI.4).

At the 100 percent level of increased flow, in a ten-year period under Plan 6, the expected spill increase at Granite Reef Dam is 140,000 acre-

ble VI.2. Allocation of Additional Flow Under Plan 6.

ccount	Expected Value[1] Per One-Year Period with Treatment Levels of 100		50		10	
	Flow, 1000 af	% of Total	Flow, 1000 af	% of Total	Flow, 1000 af	% of Tota
lan 6, Salt	19.7	5	8.5	5	1.6	4
lan 6, Verde	66.7	18	31.3	17	7.2	19
lt River Project						
Inflow	139.8		75.3		16.6	
Losses	12.5	3	8.5	5	2.1	6
Net	127.3	34	66.8	36	14.5	39
oenix Gatewater						
Inflow	20.8		10.9		2.4	
Losses	3.4	1	1.6	1	0.2	1
Spills	6.9		3.8		1.0	
Net	10.5	3	5.5	3	1.2	3
dians	0.4	1	2	1	0.4	1
ills at Granite Reef Dam	140.0	38	66.5	36	12.0	32
tal Additional Flow	369.5	103[2]	184.8	104[2]	37.0	105[2]
ange in SRP Groundwater Pumping (Gigawatt-hrs)	33.0		18.4		3.9	

robability-weighted average.
otals do not add to exactly 100 due to rounding-off and averaging.

Table VI.3. Additional Allocation Under Plan 6 from Vegetation Modification

Account	Percent Increase 1) for Treatment Level of 100%	50%	10%
Plan 6 Salt	3	1	<1
Plan 6 Verde	12	5	1
Spills at Granite Reef Dam	14	7	1
SRP Net Credit	1	<1	<1
Phoenix Net Gatewater Credit	7	4	<1
Indian Credit	-	-	-
SRP Ground Water Pumping	2	1	<1

1) Allocation increase divided by pre-increase allocation.

ble VI.4. Allocation of Additional Flow Under Modified Plan 6.

count	Expected Value[1] Per One-Year Period with Treatment Levels of					
	100		50		10	
	Flow, 1000 af	% of Total	Flow, 1000 af	% of Total	Flow, 1000 af	% of Tot
an 6 Salt	16.4	4	6.5	4	1.2	3
an 6 Verde	82.2	22	40.0	22	9.0	24
lt River Project						
Inflow	145.5		74.6		15.1	
Losses	13.4	4	7.4	4	2.1	6
Net	132.1	36	67.2	36	13.0	35
oenix Gatewater						
Inflow	22.7		11.9		2.4	
Losses	3.6	1	1.9	1	0.3	<1
Spills	8.7		4.0		0.8	
Net	10.4	3	6.0	3	1.3	3
dians	3.8	1	1.8	1	0.4	1
ills at Granite Reef Dam	125.0	34	60.8	33	12.0	32
tal Additional Flow	369.5	105[2]	184.8	103[2]	37.0	104[2]
nge in SRP Groundwater Pumping (Gigawatt-hrs)	36.0		19.2		3.8	

robability-weighted average.
otals do not add to exactly 100 due to rounding-off and averaging.

Table VI.5. Additional Allocation Under Modified Plan 6 from Vegetation Modification.

Account	Percent Increase[1) for Treatment Level of 100%	50%	10%
Plan 6 Salt	2	1	<1
Plan 6 Verde	13	6	1
Spills at Granite Reef Dam	16	8	1
SRP Net Credit	2	<1	<1
Phoenix Net Gatewater Credit	4	2	<1
Indian Credit	-	-	-
SRP Ground Water Pumping	3	1	<1

1)Allocation increase divided by pre-increase allocation.

Table VI-6. Allocation of Additional Flow Under Plan 6. (Numbers represent thousands of acre feet per one-year period.)

	% of Years When Allocation is Less Than 0	Extreme Values		Interval of Largest % Falls	
		% of yrs	Interval (1000 af)	% of yrs	Interval (1000 af)
Inflow Credits					
Plan 6, Salt Side					
100% of Increase	0	1	160-180	98	0-20
50% of Increase	0	1	80-90	99	0-10
10% of Increase	0	1	10-12	98	0-2
Plan 6, Verde Side					
100% of Increase	0	1	120-130	84	0-10
50% of Increase	0	1	50-55	86	0-5
10% of Increase	0	1	19-20	85	0-1
Salt River Project					
100% of Increase	0	1	76-80	26	0-4
50% of Increase	0	2	38-40	25	0-2
10% of Increase	0	7	7.6-8	24	0-0.4
Phoenix Gatewater Account					
100% of Increase	20	11	18-20	58	0-2
50% of Increase	20	10	9-10	58	0-1
10% of Increase	22	12	1.8-2	59	0-0.2
Indians					
100% of Increase	40	1	8-10	42	0-2
50% of Increase	42	1	8-9	40	0-1
10% of Increase	43	2	1.4-1.6	41	0-0.2
Losses and Spills					
Spills at Granite Reef Dam					
100% of Increase	2	3	125-150	91	0-25
50% of Increase	3	1	100-112	90	0-12.5
10% of Increase	3	3	12.5-15	90	0-2.5
Salt River Project Losses					
100% of Increase	0	1	6.5-7	37	0-0.5
50% of Increase	0	1	4.8-5	36	0-0.3
10% of Increase	0	14	1.0	42	0
Phoenix Losses					
100% of Increase	23	2	3-4	55	0-1
50% of Increase	27	1	2-2.5	47	0-0.5
10% of Increase	34	1	0.6-0.7	42	0-0.1

Table VI.6. Continued.

Gatewater Spilled					
100% of Increase	0	1	16-19	98	-2-1.0
50% of Increase	0	2	18.5-20	97	-1-0.5
10% of Increase	0			99	-0.2-0.1
Total Additional Flow					
100% of Increase	0	2	140-150		
50% of Increase	0	2	70-75		
10% of Increase	0	2	14-15		
Change in SRP Ground Water Pumping (Gigawatt-hours)					
100% of Increase	0	4	19-20	43	0-1
50% of Increase	0	5	9.5-10	47	0-0.5
10% of Increase	0	13	1.9-2.0	82	0-0.1

Table VI.7. Allocation of Additional Flow Under Plan 6. Assuming Utilization of 50 percent of Flood Storage Space in Cliff. (Number represent thousands of acre feet per one-year period.)

	% of Years When Allocation is Less Than 0	Extreme Values		Interval of Largest % Falls	
		% of yrs	Interval (1000 af)	% of yrs	Interval (1000 af)
Inflow Credits					
Plan 6, Salt					
100% of Increase	0	1	160-180	97	0-20
50% of Increase	0	1	10-20	99	0-10
10% of Increase	0	13	1.9-2.0	70	0.0.1
Plan 6, Verde					
100% of Increase	0	1	100-110	83	0-10
50% of Increase	0	2	45-50	83	0-5
10% of Increase	0	1	4-6	98	0-2
Salt River Project					
100% of Increase	0	4	76-80	26	0-4
50% of Increase	0	1	38-40	28	0-2
10% of Increase	0	6	7.6-8.0	32	0-0.4
Phoenix Gatewater Account					
100% of Increase	19	12	18-20	49	0-2
50% of Increase	21	12	9-10	52	0-1
10% of Increase	19	12	1.8-2.0	38	0-0.2
Indians					
100% of Increase	43	2	18-20	40	0-2
50% of Increase	43	2	9-10	40	0-1
10% of Increase	45	2	1.8-2.0	38	0-0.2
Losses and Spills					
Spills at Granite Reef Dam					
100% of Increase	3	1	175-200	91	0-25
50% of Increase	3	1	112.5-125	91	0-12.
10% of Increase	4	1	15-17.5	90	0-2.5
Salt River Project Losses					
100% of Increase	0	1	7-7.5	35	0-0.5
50% of Increase	0	4	4.8-5	36	0-0.3
10% of Increase	0	1	0.8	40	0
Phoenix Losses					
100% of Increase	24	1	4-5	53	0-1
50% of Increase	23	1	2-2.5	45	0-0.5
10% of Increase	25	1	0.9-1	46	0-0.1

Table VI.7. Continued.

Gatewater Spilled					
100% of Increase	0	2	37-40	96	-2-1.0
50% of Increase	0	2	18.5-20	96	-1-0.5
10% of Increase	0	1	0.7-1	98	-0.2-0.1
Total Additional Flow					
100% of Increase	0	2	140-150		
50% of Increase	0	2	70-75		
10% of Increase	0	2	14-15		
Change in SRP Ground Water Pumping (Gigawatt-hours)					
100% of Increase	0	2	19-20	36	0-1
50% of Increase	0	9	9.5-10	43	0-0.5
10% of Increase	0	13	1.9-2	70	0-0.1

feet (Table VI.2), which is 14 percent of the pre-increase spill (Table VI.3). There is a 91 percent chance that annual spill increases will be below 25,000 acre feet, and a 3 percent chance that annual spill increase will be from 125,000 to 150,000 acre feet (Table VI.6). For Modified Plan 6, the expected spill increases by 125,000 acre feet (Table VI.4), or 16 percent of the pre-increase level (Table VI.5). The annual distribution of spills is similar to that of Plan 6 (Table VI.7).

At the 50 percent level of increased flow, in a ten-year period, the expected spill at Granite Reef Dam under Plan 6 increases by 66,500 acre-feet. This amount is 7 percent of the pre-increase spill. Under Modified Plan 6, spills increase by 60,800 acre feet which accounts for 8 percent of the pre-increase spill.

At the 10 percent level of increased flow, in a ten-year period, spills are expected to increase by 12,000 acre feet (one percent of the pre-increase spill) under both Plan 6 and Modified Plan 6.

Salt River Project

The net volume of additional water (after losses due to evaporation and seepage are subtracted) assigned to SRP in Plan 6 varies from 39 to 34 percent of the total additional flow (Table VI.2). The net expected inflow credit to SRP at the 100 percent level of flow increase is 127,300 acre feet in a ten-year period (Table VI.2). This represents one percent of the pre-increase surface water allocation to SRP for a ten-year period (Table VI.3).

As described above regarding the existing situation, some of these spills may recharge Valley aquifers and some may be used as "free water." In addition, if Plan 6 and other CAP components were in place, the spills might be available, given some institutional changes, for CAP users.

Under Modified Plan 6, net volume to SRP is approximately 36 percent of the total additional flow (Table VI.4). At the 100 percent level of flow increase, net inflow is 132,100 acre feet, a difference of 4800 acre feet compared to Plan 6. This represents two percent of the pre-increase Modified Plan 6 surface water allocation (Table VI.5).

At the 50 percent level of increase, in a ten-year period, the expected net inflow credit to SRP is 66,880 acre-feet under Plan 6 (Table VI.2), less than one percent of SRP's pre-increase net credit. Under Modified Plan 6, net inflow credit over the ten years is similar, averaging 67,200 acre-feet (Table VI.4).

At the 10 percent level of additional streamflow, the SRP average expected net credit for a ten-year period is 14,500 acre-feet under Plan 6 (Table VI.2) and 13,000 acre-feet under Modified Plan 6 (Table VI.4). In both cases, the increase is less than one percent of the pre-increase net credit to SRP.

As discussed in Chapter V, SRP is likely to use any additional water to reduce groundwater pumping. Because Cliff Dam would not be built until sometime in the early 1900s, the proportion of agricultural to urban uses would be considerably less than it is today. To reiterate, by the year 2000, SRP predicts that agriculture will account for only 25 percent of total water demands (Salt River Project 1985).

Phoenix Gatewater Credits

The increase in net (of losses and spills) inflow credit to the Phoenix gatewater account for a ten-year period under both Plan 6 and Modified Plan 6 at all levels of streamflow increase is 3 percent of total runoff increases (Tables VI.2 and VI.4). The expected net inflow credit to Phoenix at the 100 percent level of increase under Plan 6 is 10,500 acre-

feet per ten-year period (Table VI.2). Under Modified Plan 6 it is 10,400 (Table VI.4). The net credit to Phoenix is 7 percent of its pre-increase credits under Plan 6 (Table VI.3), and 4 percent under Modified Plan 6 (Table VI.5).

At the 50 percent level of increase, in a ten-year period, the Phoenix net gatewater account would be credited with an average 5,500 acre feet due to additional flow in the system. Under Modified Plan 6, it will be credited with 6,000 acre-feet. These increases represent 4 percent of Phoenix's pre-increase credits under Plan 6, and 2 percent under Modified Plan 6.

When only 10 percent of the additional flow is present in the system, in a ten-year period, Phoenix would receive net inflow gatewater credits of 1,200 acre feet under Plan 6 and 1,300 under Modified Plan 6 (or approximately 120-130 acre-feet per year). These values represent an increase of less than one percent in gatewater credits. Again, these credits are likely to be used to offset groundwater pumping.

Other Allocations

Under both Plan 6 and Modified Plan 6 the Indian communities would receive no additional amounts of water.

The amount of water received by the Roosevelt Water Conservation District would depend on the proportion of SRP water used for agriculture purposes when Cliff Dam is in operation. For example, in the year 2000, if SRP were to receive an additional net inflow credit of 14,500 acre-feet at the 10 percent runoff increase level under Plan 6, the Roosevelt Irrigation District would be allocated 761.0 acre feet over a ten-year period.

The Buckeye Irrigation District would receive 149.5 acre feet every ten-year period. This number represents 1.1 percent of the additional water which would be diverted at Granite Reef Dam to Association users.

Plan 6 Account

Under the 100 percent level of runoff increase, the average credit to the Plan 6 beneficiary would be 19,700 acre feet on the Salt side and 66,700 acre feet on the Verde per ten-year period (Table VI.2). This represents a 3 percent increase over pre-increase net allocations on the Salt side, and 12 percent increase on the Verde side (Table VI.3). These increases are 16,400 and 82,200 acre-feet (Table VI.4), or 2 and 13 percent of pre-increase allocations (Table VI.5) for Modified Plan 6, respectively. It should be noted that while vegetative modification occurs only on the Verde Watershed, the increase in inflow in the Verde allows water levels on the Salt to remain higher, allowing the Plan 6, Salt account to accrue additional credits.

At the 50 percent level, on the Salt inflow credit is increased by 8,500 acre-feet under Plan 6, and 6,500 acre-feet under Modified Plan 6, per ten-year period. These increases are 1 percent of pre-increase credits for each plan. On the Verde, inflow credits are 31,300 acre feet for Plan 6 and 40,000 acre feet for Modified Plan 6, which represent 5 and 6 percent increases, respectively.

At the 10 percent level of increase to the Salt side 1,600 acre-feet are credited side every under Plan 6, and 1,200 acre-feet are credited under Modified Plan 6, per 10-year period. In both instances, these values represent an increase of less than 1 percent over pre-increase credits. On the Verde side, an average of 7,200 acre-feet become available per 10-year period under Plan 6, and 9,600 acre-feet under Modified Plan 6. In both

instances, the values represent increases of one percent over net pre-increase allocations.

D. Potential Beneficiaries of Water Under the Cliff Scenarios

A number of organizations have filed applications to obtain rights to any increases in water supply which might become available on the Verde River. The Department of Water Resources (DWR) will decide who receives these rights, subject to judicial review.

The prevailing opinion among those interviewed for this study is that the party or consortium of interests which finances the portion of construction costs attributable to conservation storage is most likely to be given rights to the additional water. Several organizations have expressed interest in making such a financial commitment.

The Bureau of Reclamation has applied for rights to 540,000 acre-feet of water to be used as regulatory storage water in conjunction with CAP deliveries. The primary reason the Bureau would want rights to this additional water is to be able to provide a firm CAP supply. The costs of the additional storage could be paid for by CAP users through the CAWCD, the repayment entity for the CAP. If the Bureau built and financed Cliff through the CAWCD, the most likely users would be non-Indian agriculture in Pinal and Pima counties (McCain 1983, Chase 1983b, Linsor et al. 1983; Clark 1983). Indian communities and municipal and industrial users have first priority for CAP water. Remaining water is then allocated to non-Indian agricultural users. Users in Pinal and Pima Pima County are allocated over 50 percent of supplies in this category (see page 27 for CAP allocations, and Table II-4 for the percentages of CAP water available for non-Indian irrigation in non-Indian years.)

It is also possible that the Bureau would acquire rights to the additional water to satisfy Indian water rights claims. The amounts due the Indian communities could either be determined as part of the rights allocated under the Gila River adjudication, or as part of some negotiated settlement. If this occurs, the Indians could use this water for agricultural development on their own lands. However, there is also the possiblity that they would be able to sell the water to other users and that such water could be used for purposes other than agricultural irrigation. The Ninth Circuit Court of Appeals, for example, has held that Indian allottees may transfer the "full" amount of their reserved water rights to non-Indian purchasers, and in such cases non-Indian purchasers acquires the Indian allottees' priority date (Colville Conferated Tribes v. Walson, 647F. 2nd 42 (9th Circuit 1981; cert. denied 454 US 1092, 1981). The Court, however, did not address the question whether the Indians could sell or lease their water for use off the reservation.

The cities which make up the Arizona Municipal Water Users' Association--Phoenix, Glendale, Tempe, Scottsdale, and Mesa--have also made applications with DWR for any unappropriated water in the system. The association is opposed to the new reservoir water being used for the CAP, especially if it is used outside Maricopa County (McCain, 1983). Two other organizations that have filed with DWR to appropriate water which could supplement existing supplies are the Buckeye Irrigation District and the Roosevelt Irrigation District. While these districts may lack the financial capability to undertake construction of Cliff by themselves, they are potential participants in any consortium established for this purpose.

Another potential beneficiary is the SRP. SRP's rights could come through two avenues. First, it might claim the water under the doctrine of

prior appropriation, asserting that it has rights to all the unappropriated waters from the Salt and Verde watersheds. If this were to occur, some cities and the Indian communities would be likely to argue for off-Project use of this water. Conflicts among the cities, Indian communities and the SRP would most likely result. Alternatively, the SRP could decide to finance construction of Cliff Dam, and assert rights to the additional storage water in this manner. SRP's interest in Cliff could emerge as further studies are made concerning the possibilities for hydroelectric facilities of Cliff (Juetten and Mason, 1983).

No matter what course the SRP pursues in regard to the building and financing of Cliff, the SRP will be involved in the formation of the operating criteria for the new reservoir system on the Salt-Verde rivers. The new structures of Plan 6 will complicate SRP's management of the reservoir system because: new actors such as the Corps of Engineers will be involved; the additional water will be delivered through the existing distribution system; the quality of the water could be affected; and new operating rules may affect the timing of SRP deliveries to customers (Clark, 1983).

The City of Phoenix is another candidate to finance the conservation segment. Initial cost-benefit studies by the City indicate that the project is promising (Chase, 1983b). The 75,000 acre-feet of water credits which the City can currently accumulate, over and above the actual physical 75,000 acre-feet of storage created by the spillway gates, complicate any future determination of who has the rights to any physical storage space created by Cliff Dam. If an entity other than Phoenix were to acquire the rights to Cliff, it would be necessary to negotiate some kind of agreement

with Phoenix to compensate the city for its loss in ability to gain the additional 75,000 acre-feet in water credits.

E. Affecting the Institutional Change

Determination of who would be the beneficiary of any increases in water supply that might become available on the Verde River can be made in a number of ways. Two methods could affect water whether it became available either because of additional storage space or because of increased streamflows. A third method would be used to determine rights only to water resulting from water augmentation methods such as vegetation modification.

One argument holds that regional water supplies could be allocated and managed more efficiently if it were possible to use SRP water off-Project. Precedent for this is seen in the arrangements the City of Phoenix and Salt River Project already have in terms of gatewater credits and transfer and exchange wells. Yet, currently neither the SRP nor the City of Phoenix appear to support such a proposition. However, the introduction of the DWR as a powerful, potential broker in water management could prompt the municipalities and the SRP to voluntarily create a district or set of legal arrangements which would allow water to move across Project boundaries.

In order to meet statutory requirements for a 100-year assured water supply, municipalities will need the flexibility to develop new supplies through such methods as conservation, effluent reuse, CAP, and methods of augmentation, including groundwater recharge. Agencies must be capable of managing both surface and groundwater in a manner which optimizes the utilization of both. A form of conjunctive management is being practiced by SRP and Phoenix at this time. Both use surface and groundwater to supply customer's needs as supply and demand dictate. New voluntary

arrangements could facilitate conjunctive management. They could also provide a mechanism to promote and finance various water augmentation and groundwater replenishment activities. Because serious discussions are currently taking place concerning what form basinwide management could take, prospects that some form of voluntary arrangement will determine who receives the additional water from Cliff Dam look promising.

Litigation of rights to any increased water is another possible method for determining beneficiaries. However, litigation is costly and is often a zero-sum game. Litigation as the method for determining water rights has historically created many of these problems, and further reliance on this method could impede the implementation of innovative solutions. Finally, litigation is likely to be a protracted process. The longer rights remain in limbo, the harder it is to change the status quo. This, for example, is the situation the Indians are facing today. Severe disruptions in the present system will occur if past allocations are to be changed. This increasingly makes it difficult for any court to dictate sweeping changes in current arrangements.

The third method for determining rights to water made available through the efforts of a developer is to create a new class of water. Some state statutes refer to water so created as developed water. As Arizona law now stands, any additional water sources are likely to be declared subject to allocation by the doctrine of prior appropriation. A new legal class of water could affect the legal consideration of water created by all forms of augmentation.

In an Arizona case, Salt River Valley Users' Association v. Kovacovich (411 p. 2nd 201 [1966]), the Arizona Court of Appeals held that the benefits of water savings procedures can only be captured by the party who has an existing right, or obtains a right, to the additional water. It

concluded that the doctrine of beneficial use precludes the transfer of appropriated water, "gained by water conservation practices to lands other than those to which the water was originally appurtenant." Kovacovich applied to artificial water courses and may have no application to the interpretation of water rights stemming from improvements made to the yield of a watershed.

The concept of "developed" waters has never been tested in Arizona. However, there is some indication that a developed right would not be awarded if it were tested in Arizona. Since Kovacovich in 1966, courts in other states have concluded that such increases are considered salvaged water, not developed water (the essential difference being that a right can be awarded to developed water which is out of priority with existing rights of the stream, while rights to salvaged water are subject to call by prior appropriators). This was the outcome, for example, in Southeastern Colorado Water Conservation District vs. Shelton Farms, Inc. (529 P.2nd 1321, 1975) regarding removal of phreatophytes, Giffen vs. State of Colorado, et al. (1984) regarding thinning of ponderosa pine, lodgepole pine, and Douglas fir on an area tributary to a stream, and R.J.A. Inc. vs. The water Users Association of District No. 6., State of Colorado, etc. (1984) regarding removal of peat moss in an area tributary to a stream. Thus, if a stream is currently over-appropriated, or if an entity has claim to all water (such as the SRP seems to, except for Indian rights and SRP's arrangements with Phoenix and the irrigation districts), there is little incentive for anyone but the current marginal right holder to attempt to increase flow.

While development of a new class of water could be one response, one study has concluded that at the present time the State should not attempt

to define a new class of water (Meitl, 1984). Rather, it suggested that the State continue to study the integrative management of surface water, groundwater, and effluent. Water derived from vegetative modification or other augmentation activities might then be considered within this framework, and a determination of the right of use could be bargained in specific situations rather than through special legal doctrines.

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